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THE EFFECTS OF DECOUPLED PAYMENTS ON PRODUCTION DECISIONS UNDER BASE ACREAGE AND YIELD UPDATING UNCERTAINTY: AN INVESTIGATION OF AGRICULTURAL CHEMICAL USE

A Thesis
Presented to
the Graduate School of
Clemson University

In Partial Fulfillment
of the Requirements for the Degree
Master of Science
Applied Economics and Statistics

---

by
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August 2010

Accepted by:
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ABSTRACT

When first introduced, decoupled payments were thought to have minimal impacts on current production decisions and input use. In order to comply with the Uruguay Round Agreement on Agriculture requiring all World Trade Organization (WTO) member countries to reduce trade distorting agricultural policies, in 1996 U.S. agricultural policies began shifting away from coupled payments, based on current prices, production, or output, towards decoupled payments.

However, the literature has identified several mechanisms by which decoupled payments have the potential to distort production in the current period. First, risk averse producers may increase production due to insurance and wealth effects. Second, in imperfect credit markets decoupled payments may ease constraints by increasing total wealth. Third, current production decisions may be influenced by the farmer's expectation of future decoupled payment policies, in particular after policy changes in the 2002 and 2008 Farm Bills. Fourth, input markets are affected through possible changes in the allocation of labor, land, and other inputs. Lastly, exit deterrence may result in fewer people leaving the market due to subsidizing fixed costs, declining average costs, or cross-subsidization.

In the theory section, a typical farmer's expected utility maximization problem illustrates that coupled payments are shown to affect optimal allocations of acreage (extensive margin) and production inputs (intensive margin) because they are linked to current prices, production, or inputs. In theory, decoupled payments do not affect optimal allocations of acreage and production inputs because they are not tied to current

prices, production, or inputs. However, when farmers are allowed to update historical base acres and yields upon which future decoupled payments are based, uncertainty creates a coupling mechanism between production decisions and decoupled payments.

Using FCRS and ARMS farm-level data collected by NASS between 1991 and 2008, weighted ordinary least squares regression analysis suggests a positive relationship between both decoupled payments and other government payments and per acre expenditures on agricultural chemicals. However, decoupled payments may affect the intensive margin more than other government payments. Lastly, the 2008 Farm Bill may implicitly create a coupling mechanism because base yield is calculated using an Olympic moving average, meaning that each year the historic period changes. The results suggest that current US agricultural policies are production distorting and thus may be in violation of standing WTO agreements.

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CHAPTER ONE

INTRODUCTION

The United States has a long history of supporting farmers, first through education and research in the late 1800s, then through income maintenance via price supports during the Great Depression. Price supports continued to be the main form of government support to farmers until the introduction of decoupled payments in 1996. The 1994 Uruguay Round Agreement on Agriculture required all World Trade Organization (WTO) member countries to reduce trade distorting agricultural policies and move toward decoupled support not based on current production, prices, or inputs. Decoupled direct payments were first introduced to U.S. agricultural policy with the Federal Agriculture Improvement and Reform (FAIR) Act that began implementing Production Flexibility Contract (PFC) payments to farm operators based on historic acreage and yields.

Direct payments were continued in the two subsequent Farm Bills. The Farm Security and Rural Investment Act of 2002 (FSRI) gave farmers the option of updating their base acreage and yields, essentially allowing farmers to change their historical acreage and yields upon which decoupled payments were based. The Food, Conservation, and Energy Act of 2008 (FCE) continued decoupled payments but gave farmers the option of foregoing direct payments to obtain Average Crop Revenue Election (ACRE) program payments that are based on both national market price and state average yields.

In addition, the 2008 Farm Bill permitted farmers to adjust base acreage once again to allow for the addition of newly covered commodities.

Until recently, the literature on decoupled payments concluded that, in theory, decoupled payments do not distort production decisions in the current period since the marginal production decision is not altered (Alston & Hurd, 1990; Blandford, de Gorter, & Harvey, 1989; Rucker, Thurman, & Sumner, 1995; Sumner & Wolf, 1996) However, recent research has offered several mechanisms by which decoupled payments have the potential to distort production in the current period.

The literature on decoupled payments acknowledges several mechanisms by which decoupled payments can become “coupled” to production, prices, or inputs. First, risk averse producers may increase production due to insurance and wealth effects from expectations of continued payments in the future (Hennessy, 1998). Second, imperfect credit markets allow decoupled payments to ease constraints by increasing total wealth (Burfisher & Hopkins, 2004; Goodwin & Mishra, 2006). Third, current production decisions may be influenced by expectations of future decoupled payments, in particular after liberal updating was allowed in the 2002 Farm Bill (Bhaskar & Beghin, 2010; Coble, Miller, & Hudson, 2008). Fourth, input markets are affected through possible changes in the allocation of labor and land, due to capitalization of these decoupled payments in land values (Ahearn, El-Osta, & Dewbre, 2006; Kirwan, 2009). Lastly, exit deterrence may result in fewer farms leaving the market due to subsidizing fixed costs (Chau & de Gorter, 2005), declining average costs, or cross-subsidization (de Gorter, Just, & Kropp, 2008).

All five coupling mechanisms can lead to production distortions, thus changing input use on the farm directly or indirectly through changes in acreage allocation (extensive margin), or farming the same number of acres more intensely to increase yields (intensive margin). The impact of decoupled payments on fertilizer and other agricultural chemical use might be greater than the impact on other inputs because of their dual role as inputs and possible insurance against low yields (Rajsic, Weersink, & Gandorfer, 2009). Because agricultural chemicals have a negative relationship with environmental quality, the use of these inputs is also important to study due to their potential impact on the environment.

Previous studies have focused on the effects of decoupled payments on agricultural output measured in harvested acres (Goodwin & Mishra, 2006) or aggregate farm investment (Burfisher & Hopkins, 2004) and find small but significant effects on output and investment. This thesis focuses on the effects of decoupled payments on the use of agricultural chemical inputs including pesticides, herbicides, and fertilizers.

Construction of a typical farmer's utility maximization problem illustrates the difference between the effect of coupled and decoupled payments on production. In theory, decoupled direct payments do not affect a farmer's optimal allocation of acreage or inputs because the payments are based on historic, not current, production. However, if a farmer expects updating to occur, either through government policy changes or the implicit design of the policy itself (in the case of the ACRE program introduced in 2008), he or she may alter current farm production decisions in order to maximize future profits and expected utility. The theoretical model measures production distortions through changes in optimal acreage allocation (extensive margin) and changes in optimal input allocation (intensive margin) due to the effect of decoupled payments and other government payments. The empirical model then tests the effects of decoupled payments and other government payments on fertilizer and agricultural chemical use, thus measuring possible production distortions through changes to the intensive margin.

The theoretical model is tested empirically using data from Farm Costs and Returns Surveys (FCRS) and Agricultural Resources and Management Surveys (ARMS) collected by the National Agricultural Statistics Service (NASS) between 1991 and 2008. Ordinary least squares regression analysis is used to test the hypothesis that there is a positive and significant relationship between both coupled and decoupled government payments and the use of agricultural chemicals. Chow tests indicate the presence of structural breaks around the time policy changes occurred in 1996 and 2002.

The empirical results support the hypothesis that there is a positive relationship between both decoupled direct payments and other government payments and agricultural chemical expenditures per acre. Furthermore, the marginal effects of decoupled direct payments are greater than the marginal effects of other government payments. This provides evidence that decoupled payments might affect the intensive margin more than other government payments and may therefore lead to greater distortions in production.

The thesis is organized as follows: Chapter Two provides a background on agricultural policies in the US, including an explanation of the various forms of decoupled payments. Chapter Three provides a review of the literature on mechanisms that may couple these payments to prices, production, or inputs, thus distorting production. Chapter Four examines the farmer's utility maximization problem with and without coupled and decoupled government payments. Chapter Five explains the methodology used in the empirical analysis. Chapter Six presents summary statistics and the results of the ordinary least squares regression estimations. Lastly, Chapter Seven concludes and discusses the implications of the results.

CHAPTER TWO

POLICY BACKGROUND

In 1862, the United States Department of Agriculture was created to help improve U.S. agriculture, mainly through collecting crop production statistics and dispersing the best seed varieties (Ulibarri, 1979). That role expanded with the passing of Hatch Act in 1887 creating agricultural experiment stations and the Smith-Lever Act of 1914 funding cooperative extension agencies around the country. In the early 20th century, the government supported farmers through education, innovation, and some credit and marketing programs. It was not until the Great Depression that the government saw it fit to protect farm incomes and commodity prices: the Agricultural Adjustment Act of 1933 established the first income and price supports as well as supply controls. Prices were supported through deficiency payments paid to farmers depending on the quantity they produced. Parity pricing was used to maintain the purchasing power of certain farm commodities relative to 1910-1914 levels, considered the 'Golden Age' of agriculture, with both high farm incomes and prices.

Price supports are used as a tool to redistribute wealth to farmers while providing consumers with food at low prices and are often used in markets that have more inelastic demand curves because of lack of product substitution. Under these circumstances, a price increase of one percent results in a decrease in quantity demanded of less than one percent because the consumer cannot substitute a similar good. Agricultural commodities such as cotton, feed grains (e.g., corn, oats, barley, and rye), wheat, and soybeans share this characteristic and therefore their production has been heavily subsidized (Lichtenberg & Zilberman, 1986; Rausser, 1992).

Pegging commodity prices to elevated early 20th century levels through parity pricing proved problematic because it artificially inflated prices to unsustainable levels and gave farmers incentives to produce more than consumers demanded, resulting in burdensome surpluses. Parity pricing may have also lead to capitalization, bidding up the value of farmland and other farm assets. Farmers were able to maintain the purchasing power parity policies until 1954, which helped sustain production levels during the Great Depression.

Throughout the 1930s, program-induced maintenance of high prices reduced domestic and foreign quantity demanded for U.S. commodities, requiring the government to purchase the surplus crops in order to continue supporting farmers while maintaining high prices. During World War II, the US was able to export the surplus crops to Europe, reducing the stores of grain that were building up. After the war, concern grew about a possible global recession and the collapse of agricultural prices: the Agricultural Act of 1949 reinstated the Depression-era price and income supports.

The 1954 Farm Bill was amended to remove full parity pricing in exchange for flexible price supports at less than 100 percent of parity. Flexible price supports that depended on the quantity of commodity produced continued until the 1970s, when a new Farm Bill created price supports tied to market price (not historic parity-price) and production, called coupled direct payments. Nevertheless, decades of rigid price supports set much higher than market prices resulted in “massive stock accumulation, deficiency payments, export subsidies, and land idling" (Sumner, 2007) in periods of low prices. Short periods of high prices reduced the stockpiles and allowed land to return to production.

The Food Security Act of 1985 (FSA) addressed stockpiles by lowering price support levels and reducing supply controls, allowing agricultural commodity prices to align more with the market. However, almost all payment programs were coupled to production, commodity price, or input use, thus directly affecting farm-level decision making as well as distorting foreign and domestic markets. The 1985 FSA also addressed the growing concern over the negative environmental impacts associated with agriculture by creating programs such as the Conservation Reserve Program to take highly eroded and ecologically vulnerable land out of production (Congress, 1985). However, the structure of agricultural support did not change significantly until the introduction of decoupled direct payments in the 1996 Federal Agricultural Improvement and Reform Act (FAIR) following the signing of the Uruguay Round Agreement on Agriculture (AoA) in 1994.

Decoupled Payments and the WTO

The AoA required all World Trade Organization (WTO) member countries to reduce trade distorting agricultural policies and move towards decoupled payments not based on current production, prices, or inputs. To this end, the WTO created three 'boxes,' or classifications, of agricultural domestic support and trade policies used to determine which types of policies would be allowed and which policies would be restricted to minimize trade-distortion. The boxes were named amber, blue, and green. Amber box policies, such as tariffs and market price supports, clearly distort trade and production. Developed countries with policies that fall within this box committed to reducing their total aggregate measure of support (AMS) by twenty percent within six-years; developing countries committed to a 13.3 percent reduction within ten-years (WTO, 1994).

AMS is the monetary amount of government support given to a sector of the domestic economy. It includes both government subsidies and consumer transfers that result from domestic policies that distort market prices. Current AMS is calculated per commodity and is measured by finding the difference between the world market price with historic base years 1986-1988 and the 'administered price' or sum of all amber box support explicitly or implicitly linked to the production of that commodity and multiplying that by the total quantity receiving the administered price (WTO, 1994). If this product is greater than the *de minimis* amount allowed for that commodity, it is counted in the total AMS. The *de minimis* clause of the AoA stipulates that there is no commitment to reducing amber box subsidies "in any year in which the aggregate value of the product-specific support does not exceed 5 per cent of the total value of production of the agricultural product in question" (WTO, 1994). Thus, *de minimis* support is not included in AMS calculations. However, five percent can account for a great deal: in 2000, any amber box support for corn with a total AMS less than $917 million was exempt under the *de minimis* clause (OECD, 2008b). Table 2.1 shows the U.S. *de minimis* values for major crops within the commitment time period. Because total AMS is measured without reference to a specific commodity, it is possible to reduce AMS by reducing the subsidy of one commodity while increasing the subsidy of another commodity.

Table 2.1. Annual U.S. *de Minimis* Values for Select Crops, 1995-2000

Commodity	1995	1996	1997	1998	1999	2000
Barley	$51,930	$53,763	$42,825	$34,860	$29,820	$33,549
Cotton	$328,633	$320,492	$298,577	$206,096	$190,581	$212,855
Maize	$1,198,808	$1,251,011	$1,118,630	$946,623	$858,221	$917,138
Sorghum	$73,154	$93,047	$70,007	$43,154	$46,708	$44,510
Soybeans	$730,549	$800,048	$869,811	$675,6560	$614,401	$626,066
Wheat	$496,566	$489,638	$419,368	$337,520	$285,076	$291,868

Notes: *In U.S. Millions; (OECD, 2008b)

Policies that fall within the two remaining boxes, green and blue, do not require any reduction commitments. Green box subsidies must not significantly distort trade and are funded publically, not by transfers from consumers. These include decoupled direct payments, environmental protection policies, and rural development subsidies. Blue box policies are referred to as the "amber box with conditions" (WTO, 2002) because they include supports that are linked to production like amber box policies, but are subject to production limits so they are deemed minimally trade-distortive and fully allowed within the WTO. Blue box policies include infra-marginal support policies.

Because there is only a limit on amber box subsidies and each country determines which box their policies fall into, there is an incentive to move policies to the green and blue boxes without actually minimizing the trade-distorting effects of the policies (Baffes & de Gorter, 2005). Critics of the WTO's classification of agricultural policies suggest that the system puts developing countries at a disadvantage and does not actually liberalize trade (Adams et al., 2001; Chand & Phillip, 2001; Monge-Arino, 2007). Although the system may not be as effective as presumed, it does favor the implementation of decoupled payments, as they will always fall into either the green or the blue box.

Decoupled Payments in the US

As shown in Table 2.2, between 1986 and 1995, on average 95 percent of the total value of transfers from consumers and taxpayers to farmers (Producer Support Estimate or PSE[1]) was comprised of various coupled payments based on output (e.g. market price supports), inputs (e.g. irrigation support), or current farm characteristics such as total land area, revenue, and income (e.g. deficiency payments). Decoupled payments made up less than five percent of the PSE on average, the majority of which was spent on the new Conservation Reserve Program.

Table 2.2. Production Support Estimates: Coupled and Decoupled Payment Allocations, 1986-2008

	FSA Act: 1986-1995	FAIR Act: 1996-2001	FSRI Act: 2002-2008
Total Producer Support Estimate*	$324,179	$264,436	$248,648
Coupled Payments:	95.29%	76.29%	70.51%
Based on output	47.40%	52.04%	32.09%
Based on inputs	22.33%	16.76%	25.90%
Based on current farm characteristics	25.56%	7.49%	12.52%
Decoupled Payments:	4.71%	23.71%	29.49%
Based on historic farm characteristics, production not required	0.27%	19.00%	22.58%
Based on non-commodity criteria	4.43%	4.71%	6.91%

Notes: *In U.S. Millions; (OECD, 2008b)

[1] Producer Support Estimate is "the annual monetary value of gross transfers from consumers and taxpayers to agricultural producers, measured at the farm-gate level, arising from policy measures that support agriculture, regardless of their nature, objectives or impacts on farm production or income" (OECD, 2008a)

Table 2.2 illustrates the switch from coupled deficiency payments to decoupled Production Flexibility Contracts (PFC) introduced in 1996. With the passing of the FAIR Act, decoupled payments given directly to farmers based on historical yields and acres planted became the standard form of income support for many commodity programs in the US. Decoupled direct payments were continued in the Farm Security and Rural Investment Act of 2002 (FSRI), giving farmers the option to update their base acreage and yields. Moreover, the Food, Conservation, and Energy Act of 2008 (FCE) continued decoupled direct payments but gave farmers the option of foregoing a portion of their direct payments to obtain Average Crop Revenue Election (ACRE) program payments providing participants with a revenue flow that is based on both national market price and state average yields. In addition, FCE permitted farmers to adjust base acreage once again to allow for the addition of newly covered commodities. A summary of the primary decoupled direct payments used in U.S. programs follows.

Production Flexibility Contracts (1996 -2002) and

Fixed Direct Payments (2002 -2012)

The 1996 FAIR Act eliminated many supply controls on field crops and introduced Production Flexibility Contracts (PFC). Farms producing wheat, feed grains (corn, barley, sorghum, and oats), rice, and upland cotton were allowed a one-time enrollment for a seven-year contract where eligibility was dependent on participation in a production adjustment program between 1991 and 1995.[2] Payments were determined by the product of the specific payment rate α_i for each crop *i*, historic base yield Ψ_{Hi} for each crop *i*, and

[2] The production adjustment program was from the 1990 Farm Bill.

85 percent of base acres in historic planting period H for crop i, A_{iH} (E. Young & Shields, 1996):[3]

$$\text{PFC Payment}_i = 0.85\alpha_i \Psi_i A_{iH}\ .$$

Producers were free to plant any amount of the base acres with any crop (with limitations on fruits, vegetables and specialty crops), allowing for more flexibility in the mix of commodities planted as well as the total acreage planted. For example, a farm could receive a payment based on historic corn acreage but plant wheat and oats in the fields.

In the 2002 FSRI Act, PFC were replaced with fixed direct payments (FDP) that worked much the same way. Eligibility for FDP changed from a seven-year contract to an annual agreement. Effective in 2009, the FSRI Act changed the calculation of payment acres from 85 percent of base acres in a selected commodity to 83.3 percent. Fixed direct payments also expanded the types of crops supported to include soybeans, other oilseeds, and peanuts[4] (ERS, 2002; Young & Shields, 1996), creating the possibility for farmers to update base acreage and yield.

Counter-Cyclical Payments (2002-2012)

The 2002 FSRI Act introduced counter-cyclical payments (CCP) as another form of income support, replacing the Market Loss Assistance (MLA) Program[5] introduced in 1998 as a supplement to the FAIR Act. A decline in commodity prices and projected

[3] See Appendix A for full explanation of what Payment Acres and Payment Yields cover in each Farm Bill.
[4] Special provisions are made concerning peanuts.
[5] Classification of MLA payments is disputed: Burfisher and Hopkins (2004) suggest MLA's are tied to market price and therefore fully coupled and would be classified within the Amber Box, while Adams et al. (2001) analyze MLA payments side-by-side PFC payments as fully decoupled.

farm income in 1998 paired with reduced global demand for agricultural products due to the Asian economic crisis led to Congress creating an emergency assistance package of close to $3 billion to be paid directly to farmers (ERS, 2002). Like PFC and fixed direct payments, CCP are based on historic, not current, production. However, CCP are only instituted when the effective price is less than the target price set in the FSRI Act and therefore are only "partially" decoupled as CCP are still linked to current prices (ERS, 2008).

Another difference between FSRI Act policies and previous policies is in the calculation of base acreage and yield. The FSRI Act allowed farmers three options to calculate base yield and acreage used in the CCP and FDP payout rate (ERS, 2002). First, they could keep calculating base yield the same way as before. Second, a farmer could update base yields used in the CCP payout calculation to the sum of program yields (set by FSRI Act) and 70 percent of the difference between current program yields and the farm's average yield from 1998 to 2001:

$$\Psi_{H1} = \Psi_{FSRI} + 0.70\left(\Psi_t - \bar{\Psi}_{F98-01}\right).$$

Third, farmers had the option to update base yield to 93.5 percent of the average national yields between 1998 and 2001:

$$\Psi_{H2} = 0.935\bar{\Psi}_{N98-01}.$$

Two additional ways to determine base acreage were also introduced through the CCP. First, base acreage could be calculated as the sum of the total base acreage that would have been used to calculate 2002 PFC payments plus average oilseed plantings between 1998 and 2001:[6]

$$A_{H1} = A_{98-01} + \overline{\mathrm{A}}_{98-01oil} .$$

Additionally, farmers could choose to update base acreage to include a four-year average of total acres planted and acres unable to be planted due to weather conditions between 1998 and 2001 (ERS, 2002):

$$A_{H2} = \overline{A}_{98-01} + \overline{\mathrm{A}}_{98-01idle} .$$

Average Crop Revenue Election (2008-2012)

The newest decoupled policy was introduced in the 2008 FCE Act. Average Crop Revenue Election (ACRE) payments provide participants with a guaranteed revenue flow that is based on both national market price and state average yields. Producers enrolled in ACRE must remain enrolled until 2012 and are not eligible for CCP. Enrollment in ACRE also reduces all fixed direct payments to the farm by 20 percent. The program covers an even greater number of commodities: wheat, corn, barley, grain sorghum, oats, upland cotton, rice, soybeans, other oilseeds, peanuts, dry peas, lentils, small chickpeas, and large chickpeas.

ACRE payments are contingent on national average market prices and planted yields within the state. Farmers are given direct payments totaling 90 percent of the product of the five-year benchmark state yield and the two-year ACRE program guarantee price. ACRE benchmark state yield is a commodity and state specific measure

[6] This option applies unless base acres exceed available cropland. Each producer must select one of the two options to apply to all covered commodities for both direct and counter-cyclical payments.

of the fitted average yield per planted acre; the ACRE program guarantee price is a national commodity specific two-year average market price (ERS, 2008). If ACRE revenue for the state and farm is less than the program guarantee and the benchmark farm, participants receive a payment (ERS, 2008). The ACRE program differs from previous support programs because the payments are based on moving averages of yields and prices, not a set historical time period as is seen with PFCs and FDPs. Because producers base their decision to participate in ACRE on the historic and expected variability in prices, the program works as a partially decoupled policy similar to CCP. Both ACRE and CCP are viewed as insurance programs linked to price.

Decoupled Direct Payments and Updating

With each new Farm Bill, changes in the way payment acres and payment yields are calculated permitted farmers to update their base acres and yields upon which payments are based. For example, the 2002 Farm Bill added soybeans, other oilseeds and peanuts to the list of program crops. Farmers that grew acreage of those crops were able to increase their payment, and base acres to include any soybeans, oilseeds, or peanuts planted during the base period. Further updating was permitted in 2008 when pulse crops were added to program crops. Updating can also occur with changes in how yield and acreage are calculated. As discussed above, countercyclical payments have three alternative calculations of base yields and two calculations of base acreage. If a farmer comes to expect updating or policy changes every seven to ten years, he or she may change his or her current production now to increase the payout in the future. More detail about how updating enables decoupled payments to distort production will be provided in subsequent chapters (Chapter 3 and 4).

Degrees of Decoupled Payments

Generally, decoupled payments can be defined as any measure of support that does not affect production decisions such that production at the farm level remains unchanged with or without the decoupled payment. Coupled payments can then be defined as any measure of support that affects production decisions such that production at the farm level changes with the presence of the coupled payment. Support programs, such as counter-cyclical payments and ACRE, that are linked to current commodity prices but not current production are identified as 'partially' decoupled because they are less distortive than programs linked to both price and production. Support programs, such as fixed direct payments and production flexibility contracts, that are not linked to current prices or production are identified as 'fully' decoupled payments because, in theory, they do not distort production.[7]

The USDA defines decoupled direct payments as "lump-sum income transfers to farm operators that do not depend on current production, factor use, or commodity prices and for which eligibility is based on fixed, historical criteria" (Burfisher & Hopkins, 2004). Hennessey (1998) uses a more relaxed definition of the term decoupled in his research, allowing any lump-sum payment made independent of production to count as fully decoupled, including crop disaster payments and one-time crop insurance

[7] The semantics behind the name may be interesting for readers, however the literature reviewed in the following chapter suggests that even 'fully' decoupled payments are not completely decoupled.

payments. Other authors suggest that timing and expectations play an important role in whether or not a payment is decoupled. Goodwin and Mishra (2006) argue that in order for a payment to be fully decoupled, it must only be a fixed and guaranteed lump-sum transfer to farms for a historic time period. In this framework, the 2002 FSRI Act and the 2008 FCE Act created payments that were only partially decoupled from production decisions because allowing farmers to update base acres and yields can ultimately change production decisions based on past experience and future expectations. In the context of this thesis, decoupled payments will be defined following Goodwin and Mishra's more strict definition.

Agriculture and the Environment

In the 1960s, public concern over the use of pesticides in agricultural practices and agricultural policies began to be examined within an environmental framework (Dixon, Dixon, & Miranowski, 1973; Rausser, 1992). Although soil conservation is an environmental concern, it does not have the same widespread social concern as the use of carcinogenic pesticides. During the 1960s, it became apparent that agricultural policies have implications not just for the producers and consumers of crops, but on the environment as well (Rausser, 1992). The use of pesticides in agriculture remains a heated debate and many studies show that coupled price supports increase the amount of pesticides used for each commodity (Cowan & Gunby, 1996; Dixon, Dixon, & Miranowski, 1973; Johnson, Wolcott, & Aradhyula, 1990; Lichtenberg & Zilberman, 1986; Rausser, 1992). To compound this, only 15 percent of farms participating in commodity programs (including all forms of decoupled direct payments) are also participating in conservation programs and almost half of all farms receiving commodity program payments do not receive any conservation payment (Claassen & Morehart, 2006). The recent movement towards decoupling farm support should reduce the motivation to overproduce, thus creating the positive yet unintended effect of decreasing the usage of fertilizers and other agricultural chemicals unless coupling occurs through the mechanisms discussed in detail in the next two chapters.

Although income transfers via decoupled direct payments should not, in theory, affect marginal production decisions since farmers receive the market price for the last unit they produce, such a transfer may alter the decision to enter or exit the market or may influence an individual farmer's risk preferences or alter access to credit or change a farmer's expectations about future government agricultural support policies resulting in changes to farm household consumption and investment decisions (de Gorter, Just & Kropp, 2008; Goodwin & Mishra, 2006; Hennessy, 1998; C. E. Young & Westcott, 2000). Thus decoupled direct payments can ultimately lead to a change in aggregate production and/or a change in the types and quantities of inputs used in production, with possible environmental consequences (Adams et al., 2001; Orazem & Miranowski, 1994; Wu, 1999).

Summary

The United States has a long history of supporting farmers, first through education and research, then beginning in the Great Depression with income supports via coupled price supports, a practice that was continued in various forms until the introduction of decoupled payments in the 1996 FAIR Act. Decoupled payments were introduced in the hopes of supporting farmer's income directly, without creating production distortions. Recent literature suggests that while in theory decoupled direct payments should not distort production, there are several mechanisms by which this occurs. Chapter Three will address these mechanisms directly with a review of the literature.

CHAPTER THREE

LITERATURE REVIEW

Decoupled and partially decoupled support programs are far from the transparent policies suggested by the WTO's classification scheme of amber, green and blue boxes. Decoupled income transfers such as production flexibility contracts, countercyclical payments, and fixed direct payments were thought to not affect marginal production decisions because producers receive the market price for their last unit of production. However, such a transfer may influence a farmer's production decision via the coupling mechanisms discussed in this chapter. These coupling mechanisms are likely to have an effect on farm household consumption and investment decisions, thus resulting in a change in aggregate production and/or a change in the types and quantities of inputs used in production, including fertilizer and other agricultural chemicals.

The literature on decoupled payments acknowledges several mechanisms by which decoupled payments can become 'coupled' to production, prices, or inputs. First, risk averse producers may increase production due to insurance and wealth effects from expectations of continued payments in the future (Hennessy, 1998). Second, in imperfect credit markets decoupled payments may ease constraints by increasing total wealth (Burfisher & Hopkins, 2004; Goodwin & Mishra, 2006). Third, current production decisions may be influenced by expectations of future decoupled payments, in particular after liberal updating was allowed in the 2002 Farm Bill (Bhaskar & Beghin, 2010; Coble, Miller, & Hudson, 2008). Fourth, input markets are affected through possible changes in the allocation of labor and land, due to capitalization of decoupled payments in land values (Ahearn, El-Osta, & Dewbre, 2006; Kirwan, 2009). Lastly, exit deterrence may result in fewer people leaving the market due to subsidizing fixed costs (Chau & de Gorter, 2005), declining average costs, or cross-subsidization (de Gorter, Just, & Kropp, 2008).

This literature review begins with a summary of these studies and then focuses further on studies examining the effect of decoupled payments on input use, specifically, fertilizer and other agricultural chemicals. These inputs are particularly important to understand because of their dual role as production inputs and possible insurance against low yields (Rajsic, Weersink, & Gandorfer, 2009; Roosen & Hennessy, 2003). Furthermore, if decoupled payments do distort production through increases in agricultural chemicals, there is potential for unintended environmental damage.

Coupling Mechanisms of Decoupled Payments

1. Insurance and Wealth Effects

Increases in income via decoupled payments may change a farmer's risk tolerance by reducing uncertainty associated with fluctuating commodity prices (Hennessy, 1998; Horowitz & Lichtenberg, 1993; Sandmo, 1971). Hennessy (1998) analyzes the insurance and wealth effects of decoupled and coupled payments to risk-averse farmers. Through a mathematical framework, Hennessy first proposes three ways that both decoupled and coupled payments can be linked to a profit maximizing farmer's optimal production decisions. If wealth and/or insurance effects are present, a decoupled payment received by a farmer under decreasing absolute risk aversion (DARA) will lead to an increase in a choice variable if 1) the payment increases with the level of uncertainty 2) the risk averse producer decreases production under greater uncertainty, and 3) the payment increases at a decreasing rate with the level of uncertainty (this is the second order condition for the first premise).

Hennessy then examines insurance effects alone for a farmer under constant absolute risk aversion (CARA) and finds similar results, signifying that a decoupled payment can act as an income stabilizer if a payment increases at a decreasing rate with the level of uncertainty. Conversely, a decoupled payment can create more income volatility if both the decoupled payment and the marginal increase in the payment increases with an increase in the level of uncertainty.

In order to compare decoupled and coupled payments, Hennessy lastly proposes that under coupled payment plans, producers face a profit function that includes the expected coupled payment, creating a much larger and direct effect on production decisions. In all three propositions, the payment creates an incentive for a risk averse producer to increase production when uncertainty increases by mitigating a part of uncertainty.

To understand the magnitude of these three propositions, Hennessy simulates various coupled and decoupled payment options for a 400-acre corn farm in Iowa to determine how nitrogen levels (the selected choice variable) and yield (a measure of production) change with risk. As expected, he finds that coupled payments lead to greater increases in yield and nitrogen use than do decoupled payments, with risk neutral farmers increasing nitrogen use the most and farmers under DARA increasing their nitrogen use least. Furthermore, although decoupled payments are less distortive than traditional coupled payments, they still increase input use and yield, signaling that these payments influence production decisions.

Hennessy concludes that the insurance effects of program payments are found to have the largest impact on production, followed by coupling impacts and lastly wealth effects. Under high CARA (with no wealth effect possible), adding a production flexibility contract (PFC)-style payment with a target price of $2.75 and yield of 120 bushels per acre is shown to increase nitrogen use by 12 percent and yield by 2 to 3 percent. While controlling for insurance effects by creating an equivalent lump-sum payout of $27,943, adding the same payment under DARA only increases nitrogen use by 1 percent. The large insurance effect of decoupled payments may be exacerbated because many government programs are designed for markets with higher levels of risk (and therefore high insurance effects).[8]

Changes in production associated with decoupled payments have generally been positive and small, but statistically significant (Adams et al., 2001; Coble, Miller, & Hudson, 2008; Goodwin & Mishra, 2006; Plantinga, 1996). Adams et al. (2001) used ordinary least squares regression analysis to determine whether PFC and market loss assistance (MLA) payments increased land use (measured in total crop area) in eleven Midwestern states between 1997 and 2000. The authors find that PFC and MLA payments do not have a significant relationship to land use. They also find that if the

[8] In fact, almost all government programs for agriculture require some form of crop insurance or a guarantee to not accept disaster support such as Market Loan Assistance.

payments increased by 10 percent, crop area planted would increase roughly by 0.3 percent. Contrary to previous studies, the researchers also find that when PFC and MLA payments are combined with other marketing loans, they have a statistically significant effect on total crop area, even though marketing loans themselves do not significantly impact crop area. This contradiction may be due to the higher insurance effect found in MLA payments because they are linked to current prices. The Adams et al. study may not fully capture farmers' responses to changes in marketing loans and government payments due to the short time period analyzed (only four years). Also, the study does not account for changes in crop mix, which would also have an effect on land use.

2. Imperfect Credit Markets

Administering decoupled payments in imperfect credit markets can create a coupling mechanism by increasing the farmer's total wealth and indirectly reducing constraints on credit. Burfisher and Hopkins (2004) analyze the possible effects of decoupled payments using a computable general equilibrium model and find that given perfect markets (with access to credit, risk neutrality and no insurance effect), there would be no increase of aggregate farm investment or production. However, if the credit market is not perfect, farm investment would only increase 0.2 percent and production would increase by even less. Burfisher and Hopkins suggest that moving away from all coupled payments would help the US achieve more market-oriented policies.

Goodwin and Mishra (2006) also look at credit constraints in a study of commercial farms in the Corn Belt[9] region. Farm level data from the USDA's Agricultural Resources and Management Survey (ARMS) allow the authors to create a more complete analysis than prior studies, although only four years were used (1998-2001). The authors estimate acreage equations for the three most abundant crops in the region, corn, soybean, and wheat, allowing them to examine changes not only in land use but overall crop mix as well. Variables used include crop price, farm size, government payments per acre (PFC and MLA payments), input prices (fertilizer, gasoline, and wages), wealth, a debt to asset ratio to capture credit constraints, and an insurance expenditure to total expenditure ratio as a measure of a farmer's level of risk aversion. The farm-level acreage equations also include interaction variables that capture the indirect relationship between both PFC payments and risk and PFC payments and credit constraints.

Goodwin and Mishra find the direct effect of PFC payments on corn and soybean acreage decisions to be statistically significant and small, with an additional $1.00 in payments increasing corn acreage by 0.92 acres and soybeans by 0.61 acres per farm. The interaction terms are both statistically insignificant, indicating that PFC payments between 1998 and 2001 did not impact acreage decisions indirectly through credit constraints and risk preferences. The authors note that their study did not find the "exact mechanism by which" PFC payments affect corn, soybean, and wheat acreage in

[9] The Corn Belt covers the USDA's "Heartland" resource region, a homogenous group of counties in including most counties Illinois, Indiana, Iowa, Kentucky, Minnesota, Missouri, Nebraska, Ohio, and South Dakota (Heimlich, 2000).

the Corn Belt as their analysis does not examine the possibility of intensive changes in production practice, such as reducing or increasing fertilizer or chemical applications. Furthermore, the study is limited to cross-sectional data that does not allow for comparisons of acreage decisions through time.

3. Future Expectations of Updating

As explained in Chapter Two, the 2002 and 2008 Farm Bills allow opportunities for farmers to update base acres and yields. Farmers anticipating the possibility of updating might have taken advantage of updating by planting additional acreage of crops they would have otherwise not grown, to ensure that the historic base acres on which decoupled payments are based was as high as possible. Farmer's could also increase base yield by increasing the use of inputs like fertilizer. A study by Coble, Miller and Hudson (2008) suggests that farmers face large uncertainty about future direct and counter-cyclical payments: in a 2005 survey conducted by the National Agricultural Statistics Survey (NASS), about 40 percent of respondents from Iowa and Mississippi expected base acreage and yield updating would be allowed in the next farm bill. Furthermore, 10 percent of farmers responded that they had previously increased acreage and/or inputs to 'build base' in anticipation of the 2002 Farm Bill.

Bhaskar and Bhegin's (2007) analysis of updating under uncertainty tries to quantify the extent that future expectations change risk averse farmer's behavior. They consider two possible base acreage options provided by the 2002 Farm Bill: 1) new base acreage must be a four-year average of total acres planted in 1998 to 2001 and 2) no base acreage updating. Base yields were calculated to be 93.5 percent of 1998 to 2001 average national yields.[10] The authors then use a model where farmer's maximize utility through current and future utility due to the connection created by expected future updating. As this study is more recent than the ones described above, it uses current government payments: fixed direct payments (FDP) and counter cyclical payments (CCP). Recall that both FDP and CCP are based on historic acreage and yield, however, CCP are brought about by low program crop prices (Chapter Two).

The farmer's profit function is dependent on the per-period price of crops grown, total acreage and base acreage, yields, loan rate, government payments, and total costs. Interestingly, the application of nitrogen as fertilizer appears in two parts of the model. First, yield is a function of both nitrogen and time; second, total cost is a function of current acreage and nitrogen application. Thus profit depends directly on price, acreage, and nitrogen. Since the farmer's expected utility depends on possible updating, a term is added to capture the possibility of future program income with no updating and with updating allowed for in the 2008 Farm Bill (2007-2011):

$$\gamma VB + (1-\gamma)VNB\,.$$

VB is the value of the payment to the farmer if updating is allowed and *VNB* is the value of the payment to the farmer if no updating is allowed in the 2008 Farm Bill. The model also includes a subjective probability of updating (γ) between 0 and 1: if the farmer thinks there is a 100 percent chance that updating will occur, his subjective probability is 1; if the farmer thinks there is a zero percent chance that updating will occur, γ will be

[10] See Appendix A for other updating options available in the 2002 Farm Bill.

zero. The larger γ, the greater the link between current (2003-2006) acreage and input decisions and future program crop payments.

Bhaskar and Bhegin use a stochastic dynamic programming approach to solve the two utility maximization problems (one with updating and one without) using present value estimation to derive optimal nitrogen and acreage decisions under varying degrees of certainty in updating. Optimal nitrogen application data from 1979-2003 is obtained from an experimental farm in Iowa that applies four different amounts of nitrogen to fields: 0, 80, 160 and 240 pounds per acre. The optimal nitrogen application data is used to estimate the parameters of optimal acreage for 16 states. The authors find that both average yield and average acreage increased as farmers become more certain about future updating (Bhaskar & Beghin, 2010).

When farmers were certain that updating is allowed, average acreage increases by 4.74 percent, compared to 3.04 percent for a 50 percent certainty that future updating will be allowed. Changes in yield were positive but much smaller, with a 0.05 percent change for 100 percent certainty of updating. Bhaskar and Bhegin suggest that this is because increasing nitrogen application (which is how they capture yield) has decreasing marginal returns so increasing yield is expensive. Combining these results, the average increase in output across all 16 states is 4.8 percent with full certainty of updating.

The study shows that allowing updating has a positive effect on acreage decisions and a smaller but positive effect on nitrogen use, especially if farmers are given enough time to change production decisions before the updating goes into effect. However, Bhaskar and Bhegin's model may have some over-generalizations. First, the research includes farms with only one crop, not allowing farmers to change crop mix instead of acreage allocation. Also, fertilizer use is likely to be different across crops and across states, so using nitrogen application as a strict gauge of changes in yield may lead to under- or over- estimates.

4. Input Markets

Other production decisions can be affected by decoupled payments as well, including labor and land allocations. Farmers have three ways to allocate their own labor: working on the farm, working off the farm, or leisure. As payments to farms increase, hours spent working off the farm are exchanged for farm work (El-Osta, Mishra, & Ahearn, 2004). This is true for both coupled and decoupled payments, including the 1996 FSRI's PFC payments (El-Osta, Mishra, & Ahearn, 2004).

Allocations of land can also be impacted by government payments. Because the supply of land is inelastic and supply of inputs is assumed to be perfectly elastic at the individual farm level, landowners are presumed to capture some of the benefits of government payments in the value of the land, a process called capitalization. Therefore, farmers renting land would not see government payments as an increase in wealth because they would not completely capture those payments (Kirwan, 2009). Government payments would create an incentive for landowners to keep land in agricultural use rather than forfeit this stream of income. However, 100 percent capitalization is unlikely. Kirwan (2009) suggests that due to lack of competition in the market for farmland as well as consolidation within the agriculture sector, 25 percent of government payments pass to the landlord; roughly 75 percent remains with the tenant. Other research has shown that the share of each dollar of direct payments received by farm operators that is passed through to the landlord in the form of higher rental rates can be as high as 94 percent (Lence & Mishra, 2003; Rosine & Helmberger, 1974). It is important to keep in mind that although all government payments are made to the farm operator, they may not be completely retained by him or her; the larger the proportion of decoupled payments retained by the farm operator, the greater the impact of the five coupling mechanisms described in this section (Abler & Blandford, 2005).

5. Exit Deterrence

The final coupling mechanism discussed focuses on the impact of government payments on the producer's decision to leave the farming industry. Farmers may use decoupled payments to cover costs for which they would otherwise be unable to pay for, thus creating a disincentive to leave the market (Chau & de Gorter, 2005; de Gorter, Just, Kropp, 2008).

Chau and de Gorter (2005) study the impact of loan deficiency payments and PFCs on U.S. wheat production, finding that when either government payment covers fixed costs, low profit firms are able to stay in the market longer than they would have without the payments, increasing total aggregate production. The impact to aggregate production is relatively small due to the fact that most marginal farms are not producing that much wheat, so their output is a rather small percent of the total.

In a study on cross-subsidization, de Gorter, Just and Kropp (2008) examine the U.S. dairy industry's reaction to the 2002 FSRI's Milk Income Loss Contract Program (MILC). This program pays a countercyclical payment to dairy farmers when the price of milk falls below a specified target price. However, only the first 2.4 million pounds of milk per farm per year is eligible to receive the payment (de Gorter, Just, & Kropp 2008). The authors find that both theoretically and empirically infra-marginal payments such as the MILC program can increase output as much or more than the equivalent coupled subsidy in both the short run and the long run due to exit deterrence and cross-subsidization.

Input Use and Decoupled Payments

The empirical and theoretical models discussed above find that decoupled payments have minor effects on total output but greater effects on input use and crop mix. Decoupled payments have also been found to change input decisions with possible environmental consequences (Adams et al., 2001; Orazem & Miranowski, 1994; Wu, 1999). Agricultural inputs such as pesticides, fertilizers, and herbicides can lead to environmental pollution. Since not all commodities require equal amounts of inputs, any agricultural policy's effect on crop mix should be analyzed if minimizing environmental damage is important.[11] For example, production of corn and soybeans is known to use more pesticides and fertilizers than wheat. Therefore, any shift towards corn or soybean production in favor of wheat will increase total agricultural chemical use on the farm.

Due to a lack of panel data, few studies have been conducted examining the change in crop mix due to agricultural policy. Considering the insurance effect created by decoupled payments (Hennessy 1998), a risk averse farmer receiving decoupled

[11] Since the US has many conservation policies, it is assumed that environmental quality is valued.

payments will begin planting riskier but more profitable crops. This phenomenon, called moral hazard, can change the farm's cropping patterns and crop mix. For example, "farmers who purchase crop insurance will shift land from hay and pasture to corn" (Wu, 1999), leading to negative impacts on environmental quality as corn requires more fertilizer and pesticides than hay (Claassen & Morehart, 2006; Horowitz & Lichtenberg, 1993; Monge-Arino, 2007; Plantinga, 1996; Serra et al., 2005; Wu, 1999).

Plantinga (1996) examines a case of moral hazard in dairy production, focusing on possible gains in environmental quality from reducing milk price supports in southwestern Wisconsin. This study steers away from field commodities such as corn and wheat to focus on the equally important dairy sector. The author finds that reducing price supports would decrease land allocated to dairy production and increase total forested acres. Plantinga estimates environmental quality by measuring water quality and soil erosion in the study area and finds that lower support-prices are associated with a reduction in the use of marginal land. Since erosion is more common on marginal low-quality land, Plantinga's study finds that environmental quality can increase as farmers are given an incentive to decrease milk production and increase forestry production.

A welfare analysis suggests that if the ratio of timber-to-milk prices increased 10 percent (effectively a $1.18 in average milk price), consumer surplus would increase by $8.2 to $13.3 million. While Plantinga's study is thorough, it does not consider the different possibilities of risk averse producers, so his results must be considered in a limited framework. Furthermore, he analyzes a reduction in total price supports, not a change from coupled to decoupled payments seen in current policy (Leathers & Quiggin, 1991).

Fertilizer and Other Agricultural Chemicals:

Risk Reducing or Risk Increasing Inputs?

The majority of studies on the effect of decoupled payments on the use of agricultural chemicals do not focus on the environmental implications of their findings. Instead, the use of agricultural chemical inputs is looked at in the context of a farmer's level of risk aversion (Hennessy, 1998; Horowitz & Lichtenberg, 1993; Rajsic, Weersink, & Gandorfer, 2009; Ramaswami, 1992; Roosen & Hennessy, 2003).

There is much debate on whether fertilizers and agricultural chemicals such as pesticides are risk reducing or risk increasing inputs from the farmer's standpoint. A farmer will increase consumption of inputs they view as risk reducing if they are risk averse: for example, a farmer may add more than the recommended amount of nitrogen if he thinks it will minimize the level of risk incurred at harvest.[12] On the other hand, if a risk averse farmer views fertilizer as risk increasing, he may under-apply fertilizer to reduce risk. Horowitz and Lichtenberg (1993) explain

> An input reduces risk if it adds more to output in bad states of nature than in good states of nature, since this makes output (and profit) in each state of nature more uniform and decreases yield variability. An input increases risk if it adds relatively more to output in good states than in bad ones, since that increases the discrepancy among states. In regions and/or crops where high pest infestations occur primarily when crop growth conditions are good, pesticides work by increasing output in good states of nature and are thus likely to be risk increasing.

[12] Rajsic, Weersink, and Gandorfer (2009) suggest that farmers may view fertilizer as "cheap insurance."

It is important to remember two things: first, whether or not an input is actually risk reducing or increasing is less important than the farmer's level of risk aversion because this will determine whether he or she applies less than or more than the recommended amount. If a risk loving farmer believes that fertilizer is a risk reducing input, he will apply less fertilizer per acre than his risk averse neighbor. Second, because of all agricultural chemicals' dual roles as production inputs and possible risk mitigators (or risk enhancer), it is important to understand how they interact with government payments, particularly those requiring some level of crop insurance for eligibility.

Summary

Decoupled direct payments have been shown to distort production relative to no policy being in place through at least five "coupling" mechanisms: insurance and wealth effects, credit constraints, expectations of policy updating, changes in the allocation of labor and land, and exit deterrence. Furthermore, production distortions can change input use on the farm directly or indirectly through changes in crop mix or acreage allocation. If production distortions lead to increases in the use of other agricultural chemicals, the rural environment may be negatively affected by unintended negative externalities. Additionally, the impact on the use of fertilizers and agricultural chemicals may be even more significant because of their dual role as inputs and possible insurance against low yields.

The next chapter will discuss in depth the farmer's expected utility maximization problem, focusing on how inputs and acreage allocation may change with coupled and decoupled government payments, as well as how expectations about updating can affect the utility maximization decisions.

CHAPTER FOUR

THEORY

The previous chapter illustrates the complex nature of the on-farm decision-making process farmers go through. This chapter will show that both input decisions (intensive margin) and acreage allocation (extensive margin) can change with a change in decoupled payments by comparing four potential expected utility maximization models: 1) a model without any government payments, 2) a model with only fully coupled price supports, 3) a model with decoupled payments and no updating, and lastly 4) a model with decoupled payments and updating possible. To more closely represent the real-world scenario, the final model combines fully coupled price supports, decoupled payments, and updating.

Profit Maximization without Government Payments

First, it is assumed that all farmers maximize their expected utility of wealth, including farm profits and off-farm income. Furthermore, farmers will allocate both acreage and other inputs in order to maximize profit. Equation (4.1) illustrates the expected utility maximization problem of a typical farmer where both acreage A and quantity of inputs X are choice variables. Let E be the expectation operator over the random variables, output prices and yields, and $U(\cdot)$ be a concave continuously differentiable von Neumann-Morgenstern utility function suggesting farmers are risk averse.

(4.1) $$V = \underset{\{A_{it}, X_{ijt}\}}{Max}\, E\left[\sum_{t=0}^{T} U\left(\delta^t g_t(\cdot)\right)\right]$$

where $g_t(\cdot) = \pi_t^{nogov}(\cdot) + I_t + W_{t-1}$

$$\pi_t^{nogov}(\cdot) = \sum_{i=1}^{I}\left[P_{it}\Psi_{it|\phi}A_{it} - \left(\sum_{j=1}^{J}\omega_{ijt}X_{ijt}\right) + r_{it}A_{it} + C_{it}\left(A_{it-1}\right)\right].$$

s.t. $\Psi_{it|\phi}A_{it} \le F\left(X_{ijt}, A_{it}, \varepsilon_{it}\right)$

$$\sum_{i}^{I} A_{it} = A_t$$

The function $g_t(\cdot)$ is the sum of the profit function $\pi_t^{nogov}(\cdot)$, income from off-farm activities at time t, I_{it}, and a measure of initial wealth in time t-1, W_{t-1}. The discount factor is δ^t. Profit is specified as the difference of costs and revenue. Revenue is the summation of the product of price, yield, and acres planted: the price P_{it} of the i^{th} crop at time t, yield per acre Ψ_{it} of crop i at time t subject to land quality ϕ, and acres planted A_{it} of the i^{th} crop at time t.

Costs are a summation of fixed and variable costs associated with each crop i. The cost of input j associated with the i^{th} crop at time t is the product of ω_{ijt}, the unit cost of input j, and X_{ijt}, the amount of input j associated with i^{th} crop at time t. Let r_{it} be the per-acre cost of the land input associated with the i^{th} crop at time t. Thus, for a tenant farmer renting or leasing land, r_{it} is the rental rate of land for the i^{th} crop at time t; for a owner, r_{it} is the opportunity cost associated with using the acreage for the next best use. C_{it} are fixed costs associated with the i^{th} crop at time t and are a function of production decisions in the previous time period, meaning that acreage decisions are inter-temporal.

The model has two constraints: first, the farmer is constrained by the technology he employs. Output $\Psi_{it|\phi}A_{it}$ is a function of all inputs X_{ijt}, acres planted A_{it}, and a stochastic element ε_{it} covering exogenous variants such as weather. Output is constrained by the farmer's production function. Second, it is possible to optimize profit by having idle acreage A_{idle}. Thus, if both harvested acreage and idle acreage are be included in the profit maximization model, then the constraint binds. As time is an element of the model, acreage planted (A_t) is not fixed, and A_{t-1} can be greater than, equal to, or less than current acreage as farmers buy, rent, or lease more land: $\sum A_t \neq \sum A_{t-1}$.

Production decisions are made with output price and yield uncertainty. X_{ijt} and A_{it} are choice variables and all other variable are exogenous. Costs from inputs are assumed known when acreage decisions are made because most costs are sustained at planting. Thus, within the profit function, uncertainty lies within revenue, not costs. Hence, yield and output price are treated as random variables.

First Order Conditions without Government Payments

Without loss of generality, Equations (4.2) and (4.3) below illustrate the necessary first order conditions corresponding to the farmer's utility maximization problem summarized in Equation (4.1).

(4.2) $$\frac{\partial V}{\partial X_{ijt}} = \delta^t \left[P_{it} \left\{ \frac{\partial F\left(X_{ijt}, A_{ijt}, \varepsilon_{it}\right)}{\partial X_{ijt}} \right\} - \omega_{ijt} \right] = 0$$

(4.3) $$\frac{\partial V}{\partial A_{it}} = \delta^t \left[P_{it} \left\{ \frac{\partial F\left(X_{ijt}, A_{it}, \varepsilon_{it}\right)}{\partial A_{it}} \right\} - r_{it} \right] - \delta^{t-1} \left[\frac{\partial C_{it}\left(A_{it-1}\right)}{\partial A_{it}} \right] = 0\,.$$

Equation (4.2) illustrates the standard profit maximizing condition where the input's value of its respective marginal product is equal to its own input price, ω_{ijt}, for each time *t*, crop *i* and input *j*. Equation (4.3) expresses the same is true of acreage; the value of the marginal product is equal to the rental rate r_{it}, for each time *t* and crop *i*. However, there is an additional term for time period *t-1*, because, acreage decisions are inter-temporal. For each first order condition, changes in output and input prices will change inputs and acreage. Equations (4.1) – (4.3) will be used as a baseline to compare the next three models.

Profit Maximization with Price Supports

Now consider price supports PS_{it}, a form of fully coupled government payments to farmers. PS_{it} is the sum of all per-unit subsidies and deficiency payments at price P_{it}. For example, farmers planting a specific commodity may receive a deficiency payment contingent to the set target price per commodity and the quantity produced. Equation (4.4) is the farmer's expected utility maximization problem with price supports:

$$(4.4) \qquad V = \underset{\{A_{it}, X_{ijt}\}}{Max}\, E\left[\sum_{t=0}^{T} U\left(\delta^t g_t(\cdot)\right)\right]$$

where $g_t(\cdot) = \pi_t^{cpld}(\cdot) + I_t + W_{t-1}$

$$\pi_t^{cpld}(\cdot) = \sum_{i=1}^{I}\left[(P_{it} + PS_{it})\Psi_{it|\phi}A_{it} - \left(\sum_{j=1}^{J}\omega_{ijt}X_{ijt}\right) + r_{it}A_{it} + C_{it}\left(A_{it-1}\right)\right]$$

s.t. $\qquad \Psi_{it|\phi}A_{it} \le F\left(X_{ijt}, A_{it}, \varepsilon_{it}\right)$

$$\sum_{i}^{I} A_{it} = A_t \ .$$

The profit function π changes to include the additional term PS_{it} as a function of quantity produced $\Psi_{it|\phi} A_{it}$. Also, the introduction of government payments into the expected utility function adds uncertainty about policy changes. Therefore, there is now uncertainty regarding price, yield, and policy.

First Order Conditions with Price Supports

Because price supports depend on current prices and current production, PS_{it} is included in the new first-order conditions (4.5) and (4.6) in addition to P_{it}.

$$\text{(4.5)} \qquad \frac{\partial V}{\partial X_{ijt}} = \delta^t \left[\left(P_{it} + PS_{it} \right) \left\{ \frac{\partial F\left(X_{ijt}, A_{ijt}, \varepsilon_{it} \right)}{\partial X_{ijt}} \right\} - \omega_{ijt} \right] = 0$$

$$\text{(4.6)} \qquad \frac{\partial V}{\partial A_{it}} = \delta^t \left[\left(P_{it} + PS_{it} \right) \left\{ \frac{\partial F\left(X_{it}, A_{it}, \varepsilon_{it} \right)}{\partial A_{it}} \right\} - r_{it} \right] - \delta^{t-1} \left[\frac{\partial C_{it}(A_{it-1})}{\partial A_{it}} \right] = 0 \ .$$

Acreage and input decisions depend not only on price and production, but the government issued price support as well. The first order conditions for truly decoupled payments will be shown to be the same as those in Equation (4.2) and (4.3) and hence do not distort production.

<u>Profit Maximization with Decoupled Direct Payments</u>

In theory, fully decoupled government payments should not change the profit maximizing optimal allocation of choice variables acreage *A* and inputs *X*. When the term for decoupled direct payments DP_t is added to the profit function of Equation (4.1), the following model is given.

$$(4.7) \qquad V = \underset{\{A_{it}, X_{ijt}\}}{Max} E\left[\sum_{t=0}^{T} U\left(\delta^t g_t(\cdot)\right)\right]$$

where $g_t(\cdot) = \pi_t^{dp}(\cdot) + I_t + W_{t-1}$

$$\pi_t^{dp}(\cdot) = \sum_{i=1}^{I}\left[P_{it}\Psi_{it|\phi}A_{it} - \left(\sum_{j=1}^{J}\omega_{ijt}X_{ijt}\right) + r_{it}A_{it} + C_{it}\left(A_{it-1}\right)\right] + DP_t\left(\cdot\right)$$

$$DP_t = \sum_{i=1}^{I}\left(\alpha_{it}S_{it}\Psi_{iH}\left(F_H\left(X_i, A_i, \varepsilon_i\right)\right)B_{it}\left(A_H\right)\right)$$

s.t. $\Psi_{it|\phi}A_{it} \le F\left(X_{ijt}, A_{it}, \varepsilon_{it}\right)$

$$\sum_{i}^{I} A_{it} = A_t \ .$$

Fully decoupled payments (e.g., fixed direct payments, production flexibility contracts) are represented by equation $DP_t\left(\cdot\right)$ defined as a summation over crop *i* and are a function of an α percentage of *S* payment per crop, historic yield Ψ_H per crop *i*, and base acres B_t for each crop *i*. For example, production flexibility contracts introduced in the 1996 Farm Bill calculated historic yield as an average of 1991-1994 base years, therefore farmers lacked ability to change production practices in order to manipulate the calculation of historic yield. Historic yield is a function of the production function in a historic time period *H* and base acres are a function of historic acreage A_H. Thus, decoupled direct payments are not a function of current prices, production, or inputs.

Within the *DP* function, the only variables that vary in time *t* relate to the amount of support $\alpha_{it} S_{it}$ each farmer receives, which depends on the policy in place at that time.

First Order Conditions with Decoupled Direct Payments

As mentioned before, fully decoupled payments do not change the optimal allocation of inputs and acreage relative to no government payments, as seen in the first order conditions (4.8) and (4.9) below.

$$\text{(4.8)} \quad \frac{\partial V}{\partial X_{ijt}} = \delta^t \left[P_{it} \left\{ \frac{\partial F\left(X_{ijt}, A_{ijt}, \varepsilon_{it}\right)}{\partial X_{ijt}} \right\} - \omega_{ijt} \right] = 0$$

$$\text{(4.9)} \quad \frac{\partial V}{\partial A_{it}} = \delta^t \left[P_{it} \left\{ \frac{\partial F\left(X_{ijt}, A_{it}, \varepsilon_{it}\right)}{\partial A_{it}} \right\} - r_{it} \right] - \delta^{t-1} \left[\frac{\partial C_{it}\left(A_{it-1}\right)}{\partial A_{it}} \right] = 0\,.$$

Because the policy is enacted after farmers have already made decisions in the historic time period *H*, Equations (4.8) and (4.9) are identical to Equations (4.2) and (4.3) when farmers receive no government payments. Thus, if decoupled direct payments are fully decoupled, there will be no production distortion due to the government payments, unlike coupled payments. Lastly, an additional term is added to allow for farmer's expectations of updating of base acres and yields as well as updating due to changes in government policies, a potential coupling mechanism reviewed in Chapter Three.

Profit Maximization with Decoupled Direct Payments and Updating

The literature reviewed in previous chapters also suggests that uncertainty about changes in future decoupled payments impacts a farmer's decisions today (Bhaskar & Beghin, 2010; Coble, Miller, & Hudson, 2008). Borrowing a term from Bhaskar and

Beghin (2010) that allows for expected updating, the farmer's utility maximization problem can be rewritten as

(4.10) $$V = \underset{\{A_{it}, X_{ijt}\}}{Max} E\left[\sum_{t=0}^{T} U\left(\delta^t g_t(\cdot) + \delta^{\hat{t}} h_t(\cdot)\right)\right]$$

where $g(\cdot) = \pi_t^{dp}(\cdot) + I_t + W_{t-1}$

$$\pi_t^{dp}(\cdot) = \sum_{i=1}^{I}\left[P_{it}\Psi_{it|\phi}A_{it} - (\sum_{j=1}^{J}\omega_{ijt}X_{ijt}) + r_{it}A_{it} + C_{it}\left(A_{it-1}\right)\right] + DP_t\left(\cdot\right)$$

$$DP_t = \sum_{i=1}^{I}\left(\alpha_{it}S_{it}\Psi_{iH}\left(F_H\left(X_i, A_i, \varepsilon_i\right)\right)B_{it}\left(A_H\right)\right)$$

$$h_t(\cdot) = \gamma VB + \left(1-\gamma\right)VNB$$

s.t. $$\Psi_{it|\phi}A_{it} \leq F\left(X_{ijt}, A_{it}, \varepsilon_{it}\right)$$

$$\sum_{i}^{I} A_{it} = A_t$$

$$\gamma = \left[0,1\right].$$

The function $h_t\left(\cdot\right)$ introduces a term from Bhaskar and Beghin (2010) that allows for the future policy benefits to depend on whether or not updating actually occurs and accounts for the farmer's expectation of updating occurring. Let γ be the farmer's subjective probability of future base and/or yield updating. If $\gamma = 0$, a farmer does not expect updating will be allowed in future policies. If $\gamma = 1$, a farmer is 100 percent certain that base updating will be allowed in future farm policies. The function $h_t\left(\cdot\right)$ is discounted using the discount factor $\delta^{\hat{t}}$, where $\hat{t}$ corresponds to the time period in which the future payment benefits are realized. *VB* is defined as the value of the payment if updating occurs, and *VNB* is the value of the payment if updating does not occur. If no updating is the true state of the world, then *VNB* is awarded. Conversely, if updating is the true state of the world, then *VB* is awarded.

First Order Conditions with Decoupled Direct Payments and Updating

Without loss of generality, equations (4.11) and (4.12) below illustrates the necessary first order conditions corresponding to the farmer's utility maximization problem summarized in equation (4.10).

$$(4.11)\quad \frac{\partial V}{\partial X_{ijt}} = \delta^{t}\left[P_{it}\left\{\frac{\partial F\left(X_{ijt}, A_{ijt}, \varepsilon_{it}\right)}{\partial X_{ijt}}\right\} - \omega_{ijt}\right] + \delta^{\hat{t}}\gamma\left\{\frac{\partial DP_{t}\left(\cdot\right)}{\partial X_{ijt}}\right\} = 0$$

$$(4.12)\quad \frac{\partial V}{\partial A_{it}} = \delta^{t}\left[P_{it}\left\{\frac{\partial F\left(X_{it}, A_{it}, \varepsilon_{it}\right)}{\partial A_{it}}\right\} - r_{it}\right] - \delta^{t-1}\left[\frac{\partial C_{it}(A_{it-1})}{\partial A_{it}}\right] + \delta^{\hat{t}}\gamma\left\{\frac{\partial DP_{t}\left(\cdot\right)}{\partial A_{it}}\right\} = 0$$

where $DP_{t}\left(\cdot\right) = \sum_{i=1}^{I}\left(\alpha_{it}S_{it}\Psi_{iH}\left(F_{H}\left(X_{i}, A_{i}, \varepsilon_{i}\right)\right)B_{it}\left(A_{H}\right)\right).$

Equation (4.11) consists of two parts: the first term is the standard profit maximizing condition where the value of the marginal product is equal to the input price, ω_{ijt}. The second term is due to updating. Note that the two terms have different discount factors due to the fact that the farmer receives part of the benefit in time *t* and part of the benefits in time $\hat{t}$. Equation (4.12) expresses the same is true of acreage: the value of the marginal product is equal to the rental rate r_{it}, for each time *t* and crop *i* plus an additional term included due to updating. However, there is an additional term for time period *t-1*, because, as previously mentioned, acreage decisions are inter-temporal.

If farmers have a non-zero subjective probability of updating, there is a connection between decoupled payments and input use. For each first order condition, the larger γ, the greater the link between current acreage and input decisions and future program crop payments. If $\gamma = 0$, then the term included for expectations of updating becomes zero and decoupled payments are not coupled to production through expectations of updating. If $\gamma \in (0,1]$, the expectations of updating act as a coupling mechanism between decoupled direct payments and production thus leading to current production distortions. Based on findings of Coble, Miller, and Hudson (2008),[13] it is expected that $\gamma > 0$ will be true for some, but not all farmers. The first order conditions allow decoupled payments to impact production decisions through increased acreage (extensive margin), via changing the mix of crops, or changing other input use to result in higher yields (intensive margin).

Updating was allowed twice since the introduction of decoupled payments in 1996. The 2002 FSRI Act introduced two new types of decoupled direct payment (fixed direct payments and counter-cyclical payments) that effectively changed the way base acres and yield were determined as well as expanded the number of program crops eligible for program benefits allowing farmers to reallocate their base acres.[14]

The FCE Act of 2008 created another way in which updating to base acres and yield may occur. The Average Crop Revenue Election (ACRE) program introduced in

[13] In a 2005 survey conducted by the National Agricultural Statistics Survey (NASS), 38 to 42 percent of respondents from Iowa and Mississippi expected base acreage and yield updating would be allowed in the 2008 Farm Bill.

[14] See Appendix A for specific information on changes to program yields and acres.

2008 set historic yield to an Olympic moving average, meaning that each year the historic period H changes. This policy may implicitly create a link between current acreage and input decisions and future program crop payments. For completion, the following model combines fully coupled, decoupled, and other lump sum government payments that do not effect production.

<u>Profit Maximization with All Government Payments and Updating</u>

Combining the elements of Equations (4.4), (4.7), and (4.10) and adding an additional term G_t for other lump sum government payments produces the following expected utility maximization problem.

$$(4.13)\quad V = \underset{\{A_{it},X_{ijt}\}}{Max}\, E\left[\sum_{t=0}^{T} U\left(\delta^{t} g_t(\cdot) + \delta^{t\ddot{o}} h_t(\cdot)\right)\right]$$

where $g_t(\cdot) = \pi_t^{agov}(\cdot) + I_t + W_{t-1}$

$$\pi_t^{agov}(\cdot) = \sum_{i=1}^{I}\left[(P_{it} + PS_{it})\Psi_{it|\phi}A_{it} - (\sum_{j=1}^{J}\omega_{ijt}X_{ijt}) + r_{it}A_{it} + C_{it}\left(A_{it-1}\right)\right] + DP_t\left(\cdot\right) + G_t$$

$$DP_t\left(\cdot\right) = \sum_{i=1}^{I}\left(\alpha_{it}S_{it}\Psi_{iH}\left(F_H\left(X_i, A_i, \varepsilon_i\right)\right)B_{it}\left(A_H\right)\right)$$

$$h_t(\cdot) = \gamma VB + \left(1-\gamma\right)VNB$$

s.t. $\Psi_{it|\phi}A_{it} \le F\left(X_{ijt}, A_{it}, \varepsilon_{it}\right)$

$$\sum_{i}^{I} A_{it} = A_t$$

$$\gamma = \left[0,1\right].$$

The profit function now includes price supports PS_{it}, decoupled direct payments DP_t, and lump sum payments G_t, which can include conservation payments such as the Conservation Reserve Program or Environmental Quality Incentive Program (EQIP). It is evident that although G_t increase total expected utility, it does not depend directly on the choice variables acreage A_{it} and inputs X_{ijt}. Inclusion of $h_t(\cdot)$ allows for the possibility of updating.

First Order Conditions with All Government Payments and Updating

Equations (4.14) and (4.15) are the first order conditions. Note that the term PS_{it} is again included in the optimal allocation of choice variables acreage and inputs.

$$(4.14)\quad \frac{\partial V}{\partial X_{ijt}} = \delta^t \left[\left(P_{it} + PS_{it}\right) \left\{ \frac{\partial F\left(X_{ijt}, A_{ijt}, \varepsilon_{it}\right)}{\partial X_{ijt}} \right\} - \omega_{ijt} \right] + \delta^{\hat{t}} \gamma \left\{ \frac{\partial DP_t(\cdot)}{\partial X_{ijt}} \right\} = 0$$

$$(4.15)\quad \frac{\partial V}{\partial A_{it}} = \delta^t \left[\left(P_{it} + PS_{it}\right) \left\{ \frac{\partial F\left(X_{it}, A_{it}, \varepsilon_{it}\right)}{\partial A_{it}} \right\} - r_{it} \right] - \delta^{t-1} \left[\frac{\partial C_{it}\left(A_{it-1}\right)}{\partial A_{it}} \right] + \delta^{\hat{t}} \gamma \left[\frac{\partial DP_t(\cdot)}{\partial A_{it}} \right] = 0$$

where $DP_t(\cdot) = \sum_{i=1}^{I} \left(\alpha_{it} S_{it} \Psi_{iH}\left(F_H\left(X_i, A_i, \varepsilon_i\right)\right) B_{it}\left(A_H\right)\right)$.

Government payments G_t are not included in either first order condition, illustrating that they do not influence production decisions. As in Equation (4.10) and (4.13), the larger γ, the greater the link between current acreage and input decisions and future program crop payments. If $\gamma = 0$, then Equations (4.14) and (4.15) will be equivalent to Equations (4.5) and (4.6), the optimal allocations of acreage and inputs with price supports.

<u>Summary</u>

This chapter examines the role of government payments and expectations of updating within five potential expected utility maximization problems by illustrating how coupled and decoupled payments can affect the farmer's optimal allocation of acreage and inputs. Although the equations presented in Chapter Four do not capture all five coupling mechanisms discussed in the previous chapter, the equations capture three key aspects of the literature reviewed. Production distortions can be calculated at the extensive margin through changes in total acreage, the intensive margin through changes in the amounts of inputs used, and through changes in crop mix.

Truly decoupled direct payments do not affect a farmer's optimal allocation of acreage or inputs as the payments are based on historic, not current, production. However, if a farmer expects updating to occur, either through government policy changes or the implicit design of the policy itself (in the case of ACRE), he or she may alter current farm production decisions in order to optimize future profits. The magnitude of the effects of decoupled direct payments on input use, like fertilizer and other agricultural chemicals, depends on the discount rate δ, the subjective probability of updating (γ), and the payout rate of decoupled farm subsidies ($\alpha_{it}S_{it}$) relative to the size of coupled price supports (PS_{it}). For example, if a farmer has a low discount factor, he is willing to allocate more resources to the future and may increase planting today to increase base acres and yields to reap future benefits. A farmer with a high discount factor may be less willing to change current production decisions to obtain future benefits.

The following chapters use weighted ordinary least squares regression to test the following hypothesis: there exists a positive and significant relationship between both coupled government payments and decoupled direct payments and the use of agricultural chemicals. Although the relationship between both coupled government payments and decoupled direct payments and agricultural chemical use is expected to be positive, the magnitude of the effect of decoupled direct payments may be greater than or less than the effect of coupled government payments depending on the size of coupled price supports (PS_{it}) and decoupled farm subsidies ($\alpha_{it}S_{it}$), the subjective probability of updating (γ), and the discount rate (δ).

CHAPTER FIVE

METHODOLOGY

The objective of this thesis is to test the hypothesis that there is a positive and significant relationship between both coupled and decoupled direct government payments and the use of agricultural chemicals. The magnitude of the effect of decoupled direct payments relative to coupled government payments depends on the size of coupled price supports (PS_{it}) and decoupled farm subsidies ($\alpha_{it}S_{it}$), the subjective probability of updating (γ), and the discount rate δ. Additionally, structural breaks are expected corresponding to the timing of policy changes. Weighted ordinary least squares regression analysis is used to test the hypothesis.

Data

Cross-sectional data collected annually by the U.S. Department of Agriculture (USDA) is used in the analysis. From 1984 to 1995 Farm Cost and Returns Surveys (FCRS) were collected from a representative sampling of farmers; in 1996 these surveys were replaced with Agricultural Resources and Management Survey (ARMS) questionnaires. In order to identify changes in the use of fertilizer and other agricultural chemicals due to the initial implementation of decoupled direct payments in 1996 with the passing of the FAIR Act and/or policy changes in 2002 (FSRI) and 2008 (FCE), data from 1991 to 2008 is analyzed. FCRS was collected annually from farmers and was comprised of questions relating to farm-level expenditures and returns while other surveys were used to gather information about cropping practices and input use on a field-level. In 1996, ARMS surveys integrated FCRS and the other surveys into one multi-phase, stratified, and probability-weighted dataset (Dubman, 2000). Farmers selected to participate in answering the ARMS surveys are asked questions regarding both the farm business and household. Participation is not mandated and farmers do not participate year after year.

ARMS data is collected in three phases: in Phase I, farmers are asked questions concerning what commodities have been planted that year. This phase occurs in the summer months and acts as a screening process for Phase II and III. Phase II is conducted in the fall and winter and asks randomly selected farmers from Phase I questions pertaining to cropping and management practices, production inputs, and commodity specific production costs. Phase II data is collected at the field level and focuses on a specific crop, but not all commodities are surveyed every year. Lastly, Phase III data is collected in the spring of the following year from a representative sample of farmers, including some who have already participated in Phase II. Phase III data is collected at the farm-level and includes questions regarding farm business and household finances and farm management practices, including operating expenses such as fertilizer and other agricultural chemicals. The number of farms surveyed during the Phase III process exceeds the number of farms surveyed during the Phase II process.

FCRS and Phase III ARMS data is used in this thesis. This data was selected because it contains information on decoupled payments, value of production, output, input expenses, and other farm and farmer characteristics at the farm-level. ARMS and

FCRS data are also beneficial because of the known sampling weights. Each observation is then given a weight reflecting the probability of being selected; therefore, population estimates can be constructed using a much smaller sample size than would otherwise be required. The weights (or expansion factors) change each year to reflect changes in the population as a whole (Dubman, 2000). All results are obtained using the appropriate weights.

Study Observations

Because only farmers with historic plantings of the eleven program crops receive decoupled direct payments,[15] the analysis is limited to farmers with more than 50 percent of their total value of production coming from program crop commodities. This also eliminates livestock farms. Therefore, any farmer with more than half of the total value of production coming from the following commodities is included in the analysis: general cash grain, wheat, corn, soybean, sorghum, rice, cotton, peanut, and other. General cash grain crops refer to farms that are not specializing in a specific crop, but the sum of barley, corn, oats, rice, sorghum, soybean and wheat makes up at least half of all sales revenue. Oilseeds and pulse crops (e.g., lentils, large chick peas, and small chick peas) are categorized under ‘other.’

The U.S. farming sector is made up of many very diverse geographic regions: farming conditions in California are very different than farming conditions in Kansas.

[15] As of 2008, program crops include barley, corn, cotton, oats, oilseeds, peanuts, pulse crops, rice, sorghum, soybeans, and wheat.

The USDA created nine 'farm resource regions'[16] in 1995 to help group farmland into more homogenous production zones based on geographic similarities, replacing the ten 'production regions' previously used to classify farmland in the US. These early production regions followed state boundaries, "necessarily group[ing] unlike areas together because a single State often encompasses different soils and typography" (Heimlich, 2000). For example, prior to 1995, the Appalachian production region grouped Tennessee, Kentucky, West Virginia, Virginia, and North Carolina together because of geographic proximity. However, those five states do not share similar production practices due to difference in soil, climate, and land use across the states; current resource regions designate these states to five different regions.

Thus, this analysis focuses on only the Heartland region. The Heartland spreads across 543 counties in nine states: Illinois, Indiana, Iowa, Kentucky, Minnesota, Missouri, Nebraska, Ohio, and South Dakota. However, only three states are wholly contained in the Heartland: Indiana, Illinois and Iowa. The other six states only have some counties included in the Heartland, while the other parts of the state are categorized in different resource regions. For example, it appears that all but the southernmost counties of Missouri are in the Heartland; the southern border with Arkansas is categorized as Eastern Uplands. Since the current regional classifications were not developed until 1995, this analysis focuses on an extended Heartland region encompassing all counties located in the nine states listed above. The Heartland region was chosen for several reasons. First, the Heartland boasts the largest concentration of

[16] The nine regions are: Basin and Range, Northern Great Plains, Heartland, Northern Crescent, Eastern Uplands, Southern Seaboard, Mississippi Portal, Prairie Gateway, and the Fruitful Rim (Heimlich, 2000)

cropland (27 percent of the nation's cropland) and crop value (23 percent) (Heimlich, 2000). Second, all but one program crop, peanuts, is grown there, thus farmers in this region face growing conditions that enable them to change their crop mix in order to maximize profits.

The analysis is also limited to include only farms where the primary operator claims their occupation as farm work. Farmers that have other sources of income and are farming as a hobby or in retirement might engage in a different production decision-making process. Lastly, the analysis is restricted to only include farms with total acres operated greater than zero.[17] It seems counterintuitive to report negative acres operated on a farm, however, land owners may rent or lease farm acres to other farmers through a sharecropping or rental agreement; this land is then deducted from the total number of acres owned by the primary operator, rented from others, or leased from others (ERS, 2003). Negative total acres operated would therefore suggest that more land was being rented out or leased to other producers than operated by the primary operator. In that regard, more income may come from renting land than actual production, so farms with negative operating acres are not included in the analysis.

Creating Weighted Average Costs

One clear way that fertilizer and other agricultural chemical use is affected is through changes in the prices of these two groups of inputs. Phase III data only asks about the total dollar amount spent on fertilizer and other agricultural chemicals, not the

[17] This limitation of the dataset is particularly important as almost all variables are adjusted with respect to total acres operated: having negative acres operated would change the sign of independent and dependent variables.

prices paid. Phase II data, however, does ask farmers about the per acre cost of fertilizer and other agricultural chemicals for a given commodity. Recall that Phase II data is collected annually, but not for all crops. Table 5.1 shows that from 1991 to 2008, each program crop nationwide has been surveyed only two to four times. Additionally, Phase II data is not collected at all for oilseeds, pulse crops, or peanuts.

Table 5.1. National Commodity Survey Years, 1991 – 2008

Barley	1992	2003		
Corn	1991	1996	2001	2005
Cotton	1991	1997	2003	2007
Oats	1994	2005		
Rice	1992	2000	2006	
Sorghum	1995	2003		
Soybeans	1996	2002	2006	
Wheat	1994	1998	2004	

Source: ERS 2009

The Economic Research Service division of the USDA aggregates cost data from Phase II ARMS data and FCRS data prior to 1996 in a Cost and Returns Report estimated at a regional level. Before 1996, Cost and Return regions change annually depending on the number of farms in each state producing the surveyed crop. Prior to 1996, the region that best overlaps states in the extended Heartland region is the North Central region. However, aggregate prices are only calculated in that region for corn, wheat, oats, and soybeans.

The Heartland resource region average fertilizer and other agricultural chemical costs per acre are reported for these seven crops: barley, corn, cotton, oats, sorghum, soybeans, and wheat. For this research, Cost and Returns Reports from the Heartland resource region are used after 1996 and from the North Central region for years 1991 through 1995. Table 5.2 summarizes the states included in the Cost and Return reports used to create commodity specific regional prices of fertilizer and other agricultural chemicals.

Table 5.2. Commodities Surveyed in the North Central and Heartland Regions, 1991 – 2008

	1991-1995	1996-2008
Barley	-	Heartland
Corn	Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Ohio and Wisconsin	Heartland
Cotton	-	Heartland
Oats	Illinois, Iowa, Michigan, Minnesota, Ohio and Wisconsin	Heartland
Rice	-	-
Sorghum	-	Heartland
Soybeans	Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Ohio and Wisconsin	Heartland
Wheat	Illinois, Indiana, Missouri, Ohio and Michigan	Heartland

Source: ERS 2009. Notes: The Heartland includes 543 counties in nine states: Illinois, Indiana, Iowa, Kentucky, Minnesota, Missouri, Nebraska, Ohio, and South Dakota.

ERS creates annual estimates for the years not surveyed by using price indices and USDA crop production and price statistics from other sources to better reflect year-to-year changes. Even so, technological changes or changes in survey techniques leave gaps in annual estimates for input costs (ERS, 2009). From the combined North Central and Heartland data, pricing information is missing for barley (1991-2002), cotton (1991-1996), sorghum (1991-1994), and soybeans (1997-2001). In the years missing, a 6 year adjusted price average is calculated in place of the ERS estimated price.

The commodity specific average fertilizer and other agricultural chemical costs per acre are used to create a farm-level weighted average cost of fertilizer (WACF) and a farm-level weighted average cost of agricultural chemicals (WACAC) for each far in the sample:

$$(5.1) \quad WACF = \sum_{i=1}^{7} P_{it}^{F}\left(\frac{A_{it}}{A_{Tt}}\right)$$

$$(5.2) \quad WACAC = \sum_{i=1}^{7} P_{it}^{AC}\left(\frac{A_{it}}{A_{Tt}}\right).$$

In the first equation, P_{it}^{F} is the per acre cost of fertilizer for commodity *i* in time *t* and is multiplied by the ratio of acres harvested of commodity *i* in time *t* (A_{it}) to total acres harvested of the seven program crops with fertilizer price information in time *t* (A_{Tt}). Equation (5.2) is identical to Equation (5.1) except P_{it}^{AC}, the per acre cost of agricultural chemicals for commodity *i* in time *t* replaces P_{it}^{F}. All P_{it}^{F} and P_{it}^{AC} are adjusted using the producer price index for pesticides, fertilizer, and other agricultural chemical manufacturing[18] to account for inflation and other year-to-year changes. WACF and WACAC are used in the regression equations as a measure of prices for fertilizer and other agricultural chemicals, respectively .

Model

Variables

Given the hypothesis regarding the positive relationship between agricultural chemical use and government payments (both coupled and decoupled), the effects of these payments on fertilizers and other agricultural chemicals expenditures is estimated

[18] Pesticides, fertilizer, and other agricultural chemical manufacturing is industry code 3253.

using weighted ordinary least squares regression (OLS) while controlling for other farm and farmer characteristics. As previously mentioned, decoupled direct payments are given on the farm level, so Phase III data is well suited for this investigation. However, Phase III data does not contain data on fertilizer and other agricultural chemical use, only total expenditures. Thus, fertilizer and other agricultural chemical expenditures act as the measures of fertilizer and other agricultural chemical use. These expenditures are normalized with respect to total acres operated to control for farm size.

Thus, the two dependent variables are adjusted fertilizer expenditures per total acres operated (FERT) and adjusted other agricultural chemical expenditures per total acres operated (CHEM). CHEM includes all agricultural chemicals not classified as fertilizer. Both dependent variables are adjusted using the producer price index for pesticides, fertilizer, and other agricultural chemical manufacturing. While the analysis would be improved by using quantities of fertilizer and other agricultural chemicals rather than expenditures, this information is not readily available.

A list of all variables used in the OLS regressions can be found in Table 5.3. WACF and WACAC are included as independent variables and serve as a measure of the input price of the dependent variables FERT and CHEM, respectively. An increase in WACF is expected to increase FERT; an increase in WACAC is expected to increase CHEM.

Several farm and farm characteristics are also included in the analysis. Harvested acres of the seven program crops used to calculate the weighted average cost functions are included in the analysis as independent variables (HBARLEY, HCORN, HCOTTON, HOATS, HSORGH, HSOY, and HWHEAT). These variables are normalized with respect to total acres operated. Expected signs for these variables are unclear. Since the variables are normalized, an increase in harvested acres of any one of the seven crops necessarily changes the crop mix. For example, if harvested acres of oats divided by total acres operated per farm (HOATS) decreases but total acres operated remains the same, the acres of oats must have been replaced by another crop or idled. If the replacement crop uses more fertilizer and other agricultural chemicals per acre, the decrease in HOATS will increase FERT and CHEM. If HOATS is replaced with crop using less fertilizer and other agricultural chemicals, the relationship will be negative. Total acres operated per farm (ACRESOP) is included as a size control since economies of size may be possible.

A measure of wealth is also included (WEALTH) in the regression model, calculated as total farm financial assets less total farm financial debts per total acres operated, adjusted using CPI. The expected sign for wealth is unclear. As wealth increases, fertilizer and agricultural chemical expenditures may increase because more funds are available; this would be particularly true at low levels of wealth. Conversely, since fertilizers and agricultural chemicals may act as possible insurance against low yield (Ramaswami, 1992; Hennessy 1998), there is an incentive for farmers with low levels of wealth to apply more fertilizers and pesticides.

Table 5.3. Variables Used in Weighted OLS Regression Analysis

Variable	Definition	Exp. Sign
FERT	Fertilizer expenditures divided by total acres operated, adjusted using PPI	
CHEM	Agricultural chemical expenditures divided by total acres operated, adjusted using PPI	
HBARLEY	Harvested acres of barley divided by total acres operated	(+ or -)
HCORN	Harvested acres of corn divided by total acres operated	(+ or -)
HCOTTON	Harvested acres of cotton divided by total acres operated	(+ or -)
HOATS	Harvested acres of oats divided by total acres operated	(+ or -)
HSORGH	Harvested acres of sorghum divided by total acres operated	(+ or -)
HSOY	Harvested acres of soybean divided by total acres operated	(+ or -)
HWHEAT	Harvested acres of wheat divided by total acres operated	(+ or -)
ACRESOP	Total acres operated per farm	(+)
WEALTH	Total farm financial assets less total farm financial debts (wealth) per total acres operated, adjusted using CPI	(+ or -)
AGE	Age of primary farm operator	(+ or -)
TENURE	Ratio of owned to operated acres	(+)
DP	Total decoupled direct payments per total acres operated, adjusted using CPI[a]	(+)
GOV	Government payments less decoupled payments per total acres operated, adjusted using CPI	(+)
WACF	Weighted average cost of fertilizer, adjusted using PPI[b]	(+)
WACAC	Weighted average cost of agricultural chemicals, adjusted using PPI[b]	(+)
INSURE	Ratio of insurance costs to total expenditures per farm, adjusted using CPI	(+)
SOLVE	Ratio of total farm financial debt to total farm financial assets (solvency), adjusted using CPI	(+)
DP*INSURE	Interaction term: decoupled direct payments & insurance expenditures	(-)
DP*SOLVE	Interaction term: decoupled direct payments & solvency	(-)
GOV*INSURE	Interaction term: government payments & insurance expenditures	(-)
GOV*SOLVE	Interaction term: government payments & solvency	(-)
TIME	Time trend	(+ or -)
TIMESQ	Time trend squared	(+ or -)
COUNTY	County dummy variables	(+ or -)

Notes: a- Decoupled payments includes production flexibility contracts, fixed direct payments, and counter-cyclical payments. b- WACF and WACAC include prices for all seven crops in model.

Two additional farmer characteristics that may contribute to changes in FERT and CHEM are the age of the primary operator (AGE) and the ratio of owned to operated acres (TENURE). The primary operator's total years of farm experience (YEARSEXP) are not available for all years examined, so age is used as a proxy.[19] The age of the primary operator may be positively or negatively related to fertilizer and other agricultural chemical use. A young operator may be more inclined to minimize fertilizer and chemical use due to concerns about health and/or the environment, while an older operator may be more knowledgeable about crop production and be able to reduce fertilizer and other agricultural chemical use through learning from past experiences. TENURE may affect FERT and CHEM because landowners may have a greater incentive to increase yields by increasing their use of production inputs. The expected sign for TENURE is therefore positive. Furthermore, decoupled direct payments are paid to the operator of the farm, not the owner; however an estimated 20 to 25 percent of the payment is capitalized into increased rental rates (Kirwan, 2009). Hence, tenure is an important variable.

Decoupled direct payments and all other government payments are represented by GOV and DP, respectively. DP includes production flexibility contracts, fixed direct payments, and countercyclical payments received by farmers. GOV is calculated as all other government payments. ARMS and FCRS surveys do not always distinguish between coupled payments, such as deficiency payments, and lump sum payments, such

[19] For the years 2002 through 2008, AGE and YEARSEXP have a correlation coefficient of 0.80.

as conservation program payments. Therefore, GOV represents coupled and lump sum payments. Both variables are adjusted using CPI.

Two measures of risk aversion are included in the model: INSURE and SOLVE. Following Goodwin and Mishra's (2006) estimation of a farmer's level of risk, INSURE is the ratio of insurance costs to total expenditures per farm, adjusted using CPI. The more risk averse a farmer is, the more insurance he may purchase relative to other expenditures, therefore, the expected sign is positive if fertilizer and other agricultural chemicals are risk reducing inputs. However, currently there is some debate in the literature regarding whether these inputs are risk reducing or risk increasing (Horowitz & Lichtenberg, 1993; Rajsic, Weersink, & Gandorfer, 2009; Ramaswami, 1992).

SOLVE is the solvency ratio measured as total farm financial debt to total farm financial assets, adjusted using CPI. Solvency acts as a proxy for the farm's level of credit constraint and financial risk. A farmer that is less solvent may increase the use of risk reducing inputs to insure a good yield in order to avoid defaulting on debt obligations. Second, solvency indicates whether a farmer is credit constrained: the more debt a farmer has, the less likely he can access more credit. Goodwin and Mishra (2006) use a variable similar to SOLVE as a proxy for a farmer's degree of credit constraint, thus testing the hypothesis that decoupled direct payments affect the degree of credit constraint and is a coupling mechanism for decoupled payments. A positive sign for SOLVE can therefore suggest two things: financially risky farmers view fertilizer and other agricultural chemicals as risk reducing inputs, and if a farmer is credit constrained and decoupled payments relax the credit constraint conditions, then this provides a possible coupling mechanism. SOLVE is expected to have a positive sign.

Four interaction terms (DP*INSURE, DP*GOV, GOV*INSURE, and GOV*SOLVE) are also included in the models to allow both government payments and decoupled payments to vary with different levels of risk aversion and solvency. A negative sign is expected for all interaction terms. At low levels of INSURE and SOLVE, the marginal effects of both GOV and DP on FERT and CHEM increase with increasing levels of INSURE and SOLVE. However, at higher levels of INSURE, the marginal effects of both GOV and DP on FERT and CHEM are expected to decrease due to wealth effects (Hennessy, 1998). At higher levels of SOLVE, the marginal effects of both GOV ad DP on both dependent variables are expected to increase due to reduced credit constraints (Goodwin & Mishra, 2006).

Since the data spans 17 years, a time trend is included in the model. A positive sign for TIME implies that from 1991 to 2008, fertilizer or agricultural chemical use has increased due to technological advances or other changes not captured by other regressors in the model. A positive sign for TIMESQ would imply this is occurring at an increasing rate. The expected signs of these variables are uncertain. Increased use of plants genetically modified to encourage greater yields may reduce the amounts of either production input being applied. On the other hand, increased use of low-tillage crop management may increase the use of agricultural chemicals because more weeds grow on low- or no-till land.

Lastly, dummy variables for each county (COUNTY) are included in the model to account for variability not captured by the other regressors, including: 1) transportation costs for volatile fertilizers that may change across counties, 2) soil and land quality that may differ across counties, and 3) unobserved growing conditions, such as drought and disease, that vary by county.

Regression Equations

The models can be summarized by Equations (5.3) and (5.4). The only differences between the variables used in these equations are the dependent variables and the weighted average cost functions. Note that there is no intercept in the model to allow all county dummies to remain in the model for ease of interpretation. Additionally, HCROP is a term used to identify harvested acres divided by total acres operated of the seven program crops in the model: barley (HBARLEY), corn (HCORN), cotton (HCOTTON), oats (HOATS), sorghum (HSORGH), soybeans (HSOY), and wheat (HWHEAT). By not aggregating harvested crops into one variable, changes in input use through changes to the intensive margin can be observed through changes in crop mix and farming acreage more intensely.

$$
\begin{aligned}
& FERT = \sum_{i=1}^{7} \alpha_i HCROP_i + \alpha_8 ACRESOP + \alpha_9 WEALTH + \alpha_{10} DP + \alpha_{11} GOV + \\
& \alpha_{12} AGE + \alpha_{13} TENURE + \alpha_{14} WACF + \alpha_{15} INSURE + \alpha_{16} SOLVE + \\
& \alpha_{17} DP * INSURE + \alpha_{18} DP * SOLVE + \alpha_{19} GOV * INSURE + \alpha_{20} GOV * SOLVE + \\
& \alpha_{21} TIME + \alpha_{22} TIMESQ + \sum_{k=1}^{K} \alpha_k COUNTY_k + \varepsilon
\end{aligned}
\tag{5.3}
$$

$$(5.4)\quad \begin{aligned} CHEM &= \sum_{i=1}^{7}\beta_i HCROP_i + \beta_8 ACRESOP + \beta_9 WEALTH + \beta_{10} DP + \beta_{11} GOV \\ &+\beta_{12} AGE + \beta_{13} TENURE + \beta_{14} WACAC + \beta_{15} INSURE + \beta_{16} SOLVE + \\ &\beta_{17} DP * INSURE + \beta_{18} DP * SOLVE + \beta_{19} GOV * INSURE + \beta_{20} GOV * SOLVE + \\ &\beta_{21} TIME + \beta_{22} TIMESQ + \sum_{k=1}^{K}\beta_k COUNTY_k + \varepsilon \end{aligned} .$$

The mathematical interpretations of the coefficient for AGE is:

$$(5.5)\quad \frac{\partial FERT}{\partial AGE} = \alpha_{12} .$$

In practical terms, this means that holding all else constant, a one-year increase in the age of the primary operator increases fertilizer expenditures by approximately α_{12}. Interpretations of non-interaction terms are similar to that of AGE.

The mathematical interpretations of the effects of DP and GOV are

$$(5.6)\quad \frac{\partial FERT}{\partial DP} = \alpha_{10} + \alpha_{17} INSURE + \alpha_{18} SOLVE$$

$$(5.7)\quad \frac{\partial CHEM}{\partial DP} = \beta_{10} + \beta_{17} INSURE + \beta_{18} SOLVE$$

$$(5.8)\quad \frac{\partial FERT}{\partial GOV} = \alpha_{11} + \alpha_{19} INSURE + \alpha_{20} SOLVE$$

$$(5.9)\quad \frac{\partial CHEM}{\partial GOV} = \beta_{11} + \beta_{19} INSURE + \beta_{20} SOLVE .$$

Equations (5.6) and (5.7) illustrate that the marginal effect of decoupled direct payments (DP) on FERT and CHEM depends upon the direct effect captured in coefficients α_{10} and β_{10} and the indirect effects from decoupled direct payment's interaction with INSURE and SOLVE. Similarly, Equations (5.8) and (5.9) illustrate that the marginal effect of other government payments (GOV) on FERT and CHEM depends upon the direct effect captured in coefficients α_{10} and β_{10} and the indirect effects from other government payment's interaction with INSURE and SOLVE. As INSURE and SOLVE change, so will the marginal effects of decoupled direct payments and government payments on fertilizer and other agricultural chemical use. For completeness, the marginal effects of INSURE and SOLVE are calculated as well:

$$\frac{\partial FERT}{\partial INSURE} = \alpha_{15} + \alpha_{17} DP + \alpha_{19} GOV \tag{5.10}$$

$$\frac{\partial CHEM}{\partial INSURE} = \beta_{15} + \beta_{17} DP + \beta_{19} GOV \tag{5.11}$$

$$\frac{\partial FERT}{\partial SOLVE} = \alpha_{16} + \alpha_{18} DP + \alpha_{20} GOV \tag{5.12}$$

$$\frac{\partial CHEM}{\partial SOLVE} = \beta_{16} + \beta_{18} DP + \beta_{20} GOV \,. \tag{5.13}$$

Testing Structural Breaks

Structural breaks in 1996, 2002, and 2008 are expected due to policy changes in those years. Chow tests are conducted to test for structural breaks at the time the policy change occurred. Chow tests are used in time-series data to test if coefficients of one segment of the data are statistically significantly different than the coefficients of a second time period (Chow, 1960). If decoupled direct payments increase fertilizer and other agricultural chemical use, a structural break may appear in 1996. If updating changes farmer's decisions about production inputs, specifically fertilize and agricultural chemicals, a structural break will be found in 2002. Because there is no data available after 2008, the hypothesis that changes in the 2008 Farm Bill lead to a structural break cannot be tested using this data. Chow tests are conducted comparing a model using the whole data series (data from 1991 to 2008) to the restricted model that allows all coefficients to change at three different subsets: 1991-1995 (years without decoupled direct payments), 1996-2001 (years following the introduction of decoupled payments), and 2002-2008 (years after the policy updating occurred in 2002).

An iterative Chow test is also conducted to estimate if the structural breaks due to policy implementation occurred slightly before or after the implementation, suggesting that farmers may anticipate new policy changes or, alternatively, have a lagged response to new policy changes. Breaks are considered for one and two years before and after 1996 and 2002. Since there was an additional policy change in 2008 creating ACRE, an additional break in 2006 is also assessed. This iterative Chow test procedure requires 48 additional tests to be run for each model, with the highest F-statistic determining the best fit structural breaks (Bai & Perron, 2003).

CHAPTER SIX

RESULTS

Implementing the methodology discussed in the previous chapter, the hypothesis that there exists a positive and significant relationship between both coupled government payments and decoupled direct payments and the use of agricultural chemicals and fertilizer is tested. Although a positive sign is expected for both types of payments, the magnitude of the effect of decoupled direct payments may be greater than or less than the magnitude of the effect of coupled government payments, depending on the size of coupled price supports (PS_{it}) relative to decoupled farm subsidies ($\alpha_{it}S_{it}$), the subjective probability of updating (γ), and the discount rate δ. Descriptive statistics are presented and then the weighted ordinary least squares regression results for each specified model are examined.

Summary Statistics

Summary statistics are derived using data collected in the 1991 to 1995 Farm Cost and Reports Survey and the 1996 to 2008 Agricultural Resources and Management Survey by the National Statistics Service (NASS), United States Department of Agriculture. Any interpretations and conclusions derived from the data represent the author's views and not necessarily those of NASS.

Table 6.1. Summary Statistics, 1991-2008

Variable	Mean	Std. Dev.	Min	Max
FERT	$16.48	$138.28	$0.00	$358.81
CHEM	$12.08	$100.05	$0.00	$198.28
WACF	$25.40	$76.97	$5.08	$53.58
WACAC	$16.72	$50.70	$0.66	$60.32
ABARLEY*	1.93	248.64	0	◆
ACORN*	224.91	3298.34	0	◆
ACOTTON*	1.08	384.22	0	◆
AOATS*	2.09	177.66	0	◆
AOILSEED*	2.18	337.55	0	◆
APEANUT*	0.00	0.00	0	◆
APULSE*	1.35	225.94	0	◆
ARICE*	0.64	256.03	0	◆
ASORGH*	4.70	347.36	0	◆
ASOY*	207.44	2926.94	0	◆
AWHEAT*	41.05	1706.81	0	◆
HCORN+	0.32	2.24	0	1.00
HCOTTON+	0.001	0.27	0	1.00
HSORGH+	0.01	0.46	0	0.91
HSOY+	0.30	2.09	0	1.00
HBARLEY+	0.002	0.20	0	0.75
HOATS+	0.01	0.27	0	0.64
HWHEAT+	0.04	1.04	0	0.99
ACRESOP	671.44	8,436.66	1.00	◆
TENURE	0.56	9.31	0	161.00
AGE	54	15	17	98
YEARSEXP*	29.80	14.0	0	75
WEALTH	$1,198.03	$43,369.70	$(1,240.24)	$315,709.35
NINCOME*	$52,295.87	$133,540.57	$(158,312.26)	$2,874,809.57
INSURE	0.06	0.54	0	0.83
SOLVE	0.10	5.68	0	140.34
DP	$4.88	$73.59	$0.00	$305.25
GOV	$9.81	$147.76	$(3.71)	$545.34

Notes: Number of observations is 25,071 except for WACF and WACAC, which have 24,140 observations, APULSE and AOILSEED, which have 7,214, SOLVE, which has 25,050 observations, and YEARSEXP, which has 13,957 observations. *Some variables are not in the model: YEARSEXP is defined as the primary operator's years of farm experience and NINCOME is defined as net farm income. Crop variables beginning with A are non-normalized harvested acres of all program crops. +Crop variables beginning with H represent average proportions of total harvested acres per farm. ◆Maximums cannot be reported due to disclosure restrictions on the data.

Table 6.1 contains summary statistics of all variables within the model as well as two variables that are not included due to endogeneity (net farm income, NINCOME) and missing observations in some years (primary operator's years of farm experience, YEARSEXP). Additionally, summary statistics for non-normalized harvested acres of all program crops are included (ABARLEY, ACORN, ACOTTON, AOATS, AOILSEED, APEANUT, APULSE, ASORGH, ASOY, AWHEAT). The sample size is 25,571 for all but six variables: WACF and WACAC have only 24,140 observations, APULSE and AOILSEED have 7,214 observations, SOLVE has 25,050 observations, and YEARSEXP has 13,597 observations.

Farm Characteristics

Between 1991 and 2008, average fertilizer expenditures per acres operated (FERT) is \$16.48, slightly greater than the average other agricultural chemical expenditure per acres operated (CHEM) of \$12.08. The weighted average cost of fertilizer is slightly higher than the weighted average cost of other agricultural chemicals, signifying that fertilizer used on the seven crops present in the model is on average more expensive per acre to apply than other agricultural chemicals. Alternatively, it is possible that more fertilizer is used per acre than other agricultural chemicals. The large standard deviation on both expenditures is most likely due to the differences in what each farm produces. Since not all farms produce a homogenous mix of crops, per acre expenditures for production inputs can vary dramatically between farms. An un-pooled t-test shows that there is not a significant difference in average fertilizer expenditures per acre after policy changes occurred in 1996 and 2002.[20] Additionally, an un-pooled t-test comparing average agricultural chemical expenditures per acre in 1991 through 1995 to 1996 through 2001 found no significant difference in the means.[21] However, a significant decrease in other agricultural chemical expenditures per acre is found after 2002 relative to 1996 to 2001 agricultural chemical expenditures: average CHEM between 1996 and 2001 is $13.80/acre and $10.60/acre between 2002 and 2008.[22]

Total acres operated (ACRESOP) averaged 671 acres over the 17 years. Of the total acres operated, 56 percent is owned by the primary operator and the remaining 44 percent is rented (TENURE). Average harvested acres vary widely: average harvested acres of corn per farm is the highest at 225, followed by soybeans at 207 harvested acres per farm, and wheat at just 4 harvested acres per farm, on average. Note that peanuts are not grown in the extended Heartland region and the average acres harvested rice is less than 1 acre per farm. Neither of these crops is used in the regression analysis because it is expected that rice and peanuts contribute little to nothing to fertilizer or agricultural chemical expenditures in the region analyzed.

Corn, wheat, and soybeans are the only crops grown in all nine states sampled, however corn and soybeans appear to have the largest allotment of harvested acreage relative to total acres operated. The average farm allocates 32 percent of total acres

[20] The un-pooled t-statistic comparing average fertilizer expenditures per acre in 1991-1995 to 1996-2001 is -0.153 with a reported p-value of 0.878. The un-pooled t-statistic comparing average fertilizer expenditures per acre in 1996-2001 to 2002-2008 is -0.725 with a reported p-value of 0.234.

[21] The un-pooled t-statistic comparing average agricultural chemical expenditures per acre in 1991-1995 to 1996-2001 is -0.859 with a reported p-value of 0.969.

[22] The un-pooled t-statistic comparing average fertilizer expenditures per acre in 1996-2001 to 2002-2008 is 2.162 with a reported p-value of 0.031.

operated to corn (HCORN) and 30 percent to soybeans (HSOY). See Appendix Table B.1 for a detailed table of average crop harvest per state. Furthermore, a Pearson correlation coefficient of 0.28 between HCORN and HSOY suggest that farmers harvesting corn are likely to harvest soybeans since famers generally produce these two crops in a rotation or together. Moreover, corn and wheat are negatively correlated with a Pearson correlation coefficient of 0.30, suggesting that wheat is grown when corn is not. Barley and wheat are also significantly correlated with a Pearson correlation coefficient of 0.22. Cotton is only grown in one state, Missouri, with slightly more than 14 acres harvested per farm, on average.

There is a positive and significant 0.52 correlation between harvested corn per acres operated (HCORN) and fertilizer expenditures (FERT) as well as a 0.45 Pearson correlation coefficient between harvested corn and agricultural chemical expenditures (CHEM). On average corn requires the most fertilizers and agricultural chemicals of any program crop. Soybeans (HSOY) have the next highest correlations between the dependent variables FERT and CHEM: 0.23 and 0.39, respectively.

Farmer Characteristics

The average age of the primary farm operator is 54; the youngest farmer in the sample is 17, the oldest 98. On average, the primary operator has almost 30 years of experience working on a farm (YEARSEXP). Forty-eight percent of farmers have graduated from high school and 16 percent have graduated from college.[23] The mean wealth, adjusted with respect to acres to account for farm size, is approximately $1,200

[23] More detailed information can be found in Appendix Figure B.3.

with a standard deviation of $43,000. Another measure of farm economic status is net farm income (NINCOME), which is $52,295.87 for this sample with a standard deviation of $133,540.57. The large standard deviations indicate an uneven distribution of wealth and income across the sampled farms. In fact, 74 percent of farms have a total value of production greater than $100,000 annually. On average, farms spend 6 percent of all expenditures on insurance, including subsidized crop insurance required to participate in most government crop programs. Lastly, the average farm sampled has a solvency ratio of 0.10, indicating that the farms in the sample have very little debt on average.

Government Payments

Eighty-eight percent of all sampled farms receive decoupled payments after their introduction in 1996. Farms collect $7.50 on average in decoupled direct payments (DP) per operated acre (after 1996) and almost twice that in all other government payments (GOV). Again, there is a wide range of farms represented and large standard deviations for both GOV and DP ($147.76 and $73.59, respectively). Between 1996, when decoupled payments were introduced, and 2008, the average payment per acre fluctuated (see Appendix Figure B.1). The first four years saw an almost doubling of DP, followed by three years of declining payments and then an increase until 2005, when decoupled payments per acre hit their maximum value of $10.93. Participation in direct decoupled payment programs (specifically production flexibility contracts, countercyclical payments, and fixed direct payments) does not seem to follow the same trend, suggesting that farmers do not enroll in the program in anticipation of higher payments.

Regression Analysis Results: 1991-2008

To test our hypotheses that both decoupled direct payments and coupled payments have a significant and positive effect on fertilizer and other agricultural chemical use, weighted ordinary least squares regression procedures are used to estimate Equations (6.1) and (6.2) below using the appropriate sample weights.[24] The resulting coefficients and standard errors are reported in Table 6.2.

$$\begin{aligned}(6.1)\quad & FERT = \sum_{i=1}^{7}\alpha_i HCROP_i + \alpha_8 ACRESOP + \alpha_9 WEALTH + \alpha_{10} DP + \alpha_{11} GOV + \\ & \alpha_{12} AGE + \alpha_{13} TENURE + \alpha_{14} WACF + \alpha_{15} INSURE + \alpha_{16} SOLVE + \\ & \alpha_{17} DP * INSURE + \alpha_{18} DP * SOLVE + \alpha_{19} GOV * INSURE + \alpha_{20} GOV * SOLVE + \\ & \alpha_{21} TIME + \alpha_{22} TIMESQ + \sum_{k=1}^{K}\alpha_k COUNTY_k + \varepsilon\end{aligned}$$

$$\begin{aligned}(6.2)\quad & CHEM = \sum_{i=1}^{7}\beta_i HCROP_i + \beta_8 ACRESOP + \beta_9 WEALTH + \beta_{10} DP + \beta_{11} GOV \\ & +\beta_{12} AGE + \beta_{13} TENURE + \beta_{14} WACAC + \beta_{15} INSURE + \beta_{16} SOLVE + \\ & \beta_{17} DP * INSURE + \beta_{18} DP * SOLVE + \beta_{19} GOV * INSURE + \beta_{20} GOV * SOLVE + \\ & \beta_{21} TIME + \beta_{22} TIMESQ + \sum_{k=1}^{K}\beta_k COUNTY_k + \varepsilon\end{aligned}$$

Model 1: Fertilizers (1991 – 2008)

The model with fertilizer expenditures per acre as a dependent variable (Model 1) has 24,118 observations over the 17-year time period of 1991 to 2008. The effects of the county dummy variables (COUNTY) are not reported due to the large number of counties in the sample (764 counties are represented). All but two variables (WEALTH and

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[24] Appropriate weights were assigned using professional expertise from the U.S. Economic Research Service.

GOV*SOLVE) have coefficients that are statistically different than zero at a 5 percent level of significance (Table 6.2).

All harvested acres of program crops per total operated acres have a positive and significant relationship with fertilizer expenditures, with harvested corn acreage having the largest coefficient and oats having the smallest. Although precise relationships should not be implied by the coefficients, the magnitudes suggest that an increase in acreage allotted to corn will increase fertilizer expenditures more than a similar increase in acreage allotted to oats. These results reflect the important role of crop mix in the consumption of fertilizer. Total acres operated had a small statistically significant positive relationship with fertilizer expenditures per acre. This implies the effect of economies of size is small and a farmer's crop mix is more important than total acreage when determining fertilizer expenditures per acre. A positive relationship is also found between TENURE and FERT: the more land the primary operator owns relative to renting, the greater fertilizer expenditures per acre are, suggesting that capitalization may play an important role in input decisions on the farm.

Because of the presence of the four interaction terms (DP*INSURE, DP*SOLVE, GOV*INSURE, and GOV*SOLVE), Equations (5.6), (5.8), (5.10), and (5.12) presented in the methodology chapter are used to calculate the marginal effect at the mean of decoupled direct payments per acre (DP), other government payments per acre (GOV), the ratio of insurance costs to total expenditures per farm (INSURE), and solvency (SOLVE) on fertilizer expenditures per acre, respectively.[25]

[25] Marginal effects and the means at which they were calculated are found in Appendix C.

The marginal effect of INSURE on fertilizer expenditures per acre evaluated at the mean is -32.25, which is unexpectedly negative. A positive sign is expected for the effect of insurance expenditures because the more risk-averse a farmer is the more he should increase his use of risk-reducing inputs such as fertilizer. However, the measure for risk-aversion (INSURE) is significantly negative indicating an increase in the insurance ratio leads to decreased fertilizer expenditures per acre.

There are a few possible justifications for this unexpected result. First, some farmers may view fertilizer as a risk-increasing input, meaning that risk averse farmers would decrease their use of fertilizer. Whether fertilizer is risk-increasing or decreasing is debated in the literature (Horowitz & Lichtenberg, 1993; Rajsic, Weersink, & Gandorfer, 2009; Ramaswami, 1992). Second, insurance expenditures as a proportion of total farm expenditures may be too simplistic a measure of farmer's risk aversion, particularly within this model, where there may be some endogeneity issues due to the dependent variable FERT being a portion of total expenditures. Furthermore, an increase in the effect of INSURE may be caused by a decrease in total expenditures (the denominator of the ratio).

Contrarily, the marginal effect evaluated at the mean of SOLVE, an estimation of the level of a farmer's credit constraint, is 0.86. If a farmer is less solvent (and therefore has a greater solvency ratio), he will increase risk-reducing inputs like fertilizer because the farmer wants to insure a good yield and ensure he will not default on his debt obligations.

Table 6.2. Fertilizer and Other Agricultural Chemical Weighted OLS Regression Results, 1991-2008

	Models			
	Fertilizer (1)		Other Agricultural Chemicals (2)	
	Coeff.	Std. Error	Coeff.	Std. Error
HBARLEY	13.43***	3.84	1.59	2.91
HCORN	28.70***	0.67	15.77***	0.39
HCOTTON	16.41***	3.66	35.84***	2.97
HOATS	6.97**	2.83	-13.72***	2.20
HSORGH	16.40***	1.76	11.79***	1.31
HSOY	8.36***	0.72	11.86***	0.37
HWHEAT	15.24***	1.01	7.94***	0.88
ACRESOP	0.0005***	0.00009	0.0004***	0.00007
WEALTH	0.000009	0.00007	0.0003***	0.00006
DP	0.19***	0.02	0.17***	0.01
GOV	0.11***	0.01	0.04***	0.01
AGE	-0.03***	0.01	-0.003	0.004
TENURE	2.53***	0.21	1.35***	0.15
WACF/WACAC[a]	0.17***	0.02	0.12***	0.03
INSURE	-23.78***	2.50	-17.98***	1.85
SOLVE	1.58***	0.55	2.34***	0.41
DP*INSURE	-0.74***	0.27	-0.57***	0.20
DP*SOLVE	-0.09**	0.04	-0.20***	0.03
GOV*INSURE	-0.49***	0.14	0.18*	0.10
GOV*SOLVE	-0.03	0.04	0.12***	0.03
TIME	-0.23***	0.06	0.68***	0.04
TIMESQ	0.02***	0.003	-0.04***	0.003
Observations	24,118		24,118	
Adjusted R Squared	0.399		0.342	

Notes: *, **, *** indicate parameter significance at α = 10%, 5% and 1%, respectively. a- WACF used for Fertilizer model, WACAC used for Agricultural Chemical model. County dummy variables are not reported due to the large number of counties (764) in the sample. Additionally, the intercept is dropped to allow all counties to remain in model.

As hypothesized, an increase in decoupled direct payments and government payments both increase fertilizer expenditures per acre by a small but statistically significant amount. Coupled government payments based on production, inputs, or prices are known to increase input use. However, decoupled direct payments are, in theory, not based on production, inputs, or prices unless they are linked by any of the coupling mechanisms previously discussed. The results for modeling fertilizer as the dependent variable suggest that decoupled direct payments may affect a farmer's decision to use fertilizers, although without panel data causality cannot be tested. The marginal effect of government payments on fertilizer use per acre operated calculated at the mean is 0.08. The marginal effect of decoupled direct payments on fertilizer use per acre operated evaluated at the mean is 0.138, suggesting that the effect of DP on FERT is greater than the effect of GOV on FERT.

Furthermore, the results for DP*INSURE and DP*SOLVE suggest that there are three avenues by which decoupled direct payments may affect fertilizer expenditures per acre: first, directly as seen through DP, second, indirectly through changes in risk preferences (DP*INSURE), and third, indirectly through changes in financial risk preferences (DP*SOLVE).

These results confirm the hypothesis: the effects of government payments and decoupled direct payments on fertilizer use are both positive. Also, there is a greater marginal effect of decoupled direct payments than other government payments. This indicates that decoupled payments might affect the intensive margin more than other government programs and hence decoupled payments could ultimately lead to larger production distortions or greater negative environmental impacts. GOV includes lump sum payments that have no effect on production and production distorting price supports, thus the effect of GOV serves as a lower bound on the effect of coupled payments on fertilizer expenditures per acre.

The effect of age on fertilizer expenditures per acre is negatively significant (AGE): as a farmer's age increases, fertilizer expenditures per acre decrease, although not by a large magnitude. This supports the proposition that farmers with more experience[26] use less fertilizer, perhaps because they are familiar with other methods, or are reluctant to apply more fertilizer. The two time trend variables (TIME and TIMESQ) together suggest that over time, fertilizer expenditures have decreased at an increasing rate. This may be due to technological advances in production practices such as genetically modified crops that may require less fertilizer.

Model 2: Other Agricultural Chemicals (1991 – 2008)

A weighted ordinary least squares regression is also estimated for other agricultural chemical expenditures per acre with similar results. The analysis uses 24,118 observations. Only two variables were insignificant at the 5 percent significance level: harvested acres of barley per operated acres (HBARLEY) and age. The time trends (TIME and TIMESQ) suggest that holding all else constant, as time progresses, agricultural chemical expenditures per acre operated increase at a decreasing rate.

Contrary to Model 1, the agricultural chemical model does not have positive coefficients associated with the ratio of program crops to total operated acres for all crops. The effect of HOATS is negative and significantly related to agricultural chemical expenditure per acre operated, suggesting that oats require fewer agricultural chemicals to produce than the other program crops in the model. Like in the fertilizer model, the

[26] Recall that AGE was used as a proxy for farm experience because of the high correlation (0.80) between AGE and YEARSEXP.

coefficients associated with the seven program crops in the agricultural chemical model are not the same for all crops. For example, the coefficient for HCOTTON implies that a 1 percent increase of total acres operated used for harvesting cotton increases agricultural chemical expenditures per acre by approximately $36.00, while a 1 percent increase of total acres operated used for harvesting corn increases CHEM less than half that amount. The coefficient for HBARLEY is not significant perhaps because of the low average barley acres harvested. Similar to Model 1, total acres operated is statistically significant but small.

The marginal effect of INSURE evaluated at the mean is -17.98, which may imply that other agricultural chemicals may also be a risk-increasing input. The marginal effect of SOLVE evaluated at the mean is 2.34, suggesting that as a farm become more credit constrained, it increases expenditures of other agricultural chemicals per acre.

Coefficients for government payments per acres operated (GOV) and decoupled direct payments per acres operated (DP) are both positive and small, but statistically significant. Furthermore, the coefficients on the interaction terms with DP are statistically significant and negative, indicating that decoupled direct payments affect agricultural chemical expenditures through changes in risk preference (DP*INSURE) and/or credit constraints (DP*SOLVE) (Goodwin & Mishra 2006). Coefficients on the interaction terms for government payments are negative, indicating that the marginal effect of government payments on agricultural chemicals decreases with an increase in solvency and/or insurance expenditures. The marginal effects of GOV and DP calculated at the mean are 0.06 and 0.11, respectively, giving similar results to those found in the fertilizer model: the effects of government payments and decoupled direct payments on agricultural chemical use are both positive. Also, the marginal effect of decoupled direct payments is greater than the marginal effects of other government payments evaluated at the means, indicating that decoupled payments may have greater effects on the intensive margin than other government payments.

Regression Analysis Results: Structural Breaks

Structural breaks in 1996, 2002, and 2008 are expected due to policy changes in those years. Chow tests are conducted to test structural breaks at the time the policy changes occurred. Because no data is available after 2008, the hypothesis that a structural break occurs in 2008 is not possible to test. A Chow test is used to find the hypothesized structural breaks when the data is split into three subsets: 1991-1995, 1996-2001, and 2002-2008. The F-statistic for the fertilizer model with structural breaks in 1996 and 2002 is 18.05 (p=0). For the other agricultural chemicals model with structural breaks in 1996 and 2002, the F-test is 13.46 (p=0).

In order to test if there was any anticipation of policy changes or lags in farmer's decision to update due to policy changes, additional Chow tests are conducted for one and two years before and after each policy change. Since there was an additional policy change in 2008 creating ACRE, Chow tests are also conducted adding an additional break in 2006. This iterative Chow test procedure requires 48 additional tests to be run for each model, with the highest F-statistic determining the best fit structural breaks.[27] This

[27] Iterative Chow tests are found in Appendix Tables D.1 and D.2.

process finds that for fertilizer, structural breaks in 1996 and 2004 are a better fit than the hypothesized breaks in 1996 and 2002. For other agricultural chemicals, the best fit structural breaks occur in 1996 and 2000. This section begins with an explanation of the hypothesized fertilizer and other agricultural chemical models and then compares the results to the respective models with structural breaks determined by the iterative Chow tests.

Fertilizers (Structural Breaks in 1996 & 2002)

Table 6.3 reports the weighted OLS regression results for the model with fertilizer expenditures per acre as the dependent variable with structural breaks in 1996 and 2002. There are 4,755 observations in the first subset (1991-1995), 6,788 observations in the second subset (1996-2001), and 12,575 observations in the third subset (2002-2008). The adjusted R^2 values are 0.50, 0.50, and 0.42, respectively, all of which are higher than the adjusted R^2 value of 0.40 for fertilizer Model 1 using all years. The first subset (1991-1995) does not have coefficients or standard errors for decoupled payments or the interaction terms including that variable because before 1996, there were no decoupled direct payments. Thus, all government payments are captured in the GOV variable. The magnitude of the coefficient corresponding to government payments per acres operated in this time period is almost triple the magnitude of the same variable in Model 1 using all the sampled years.

Very few of the coefficients have changed sign or magnitude compared to Table 6.2, however the coefficient for HOATS is five times larger than in Model 1. Another change from the first model is that the interaction term between government payments and solvency is statistically significant in the 1991 to 1995 subset. Whether these coefficients are statistically different from their corresponding coefficients in the whole model using all sample years has not been tested, but it is important nonetheless to note of these slight changes in the coefficients.

Table 6.3. Fertilizer Weighted OLS Regression Results with Structural Breaks in 1996 and 2002

	Subsets					
	1991-1995		1996-2001		2002-2008	
	Coeff.	Std. Error	Coeff.	Std. Error	Coeff.	Std. Error
HBARLEY	17.52**	6.34	3.30	8.76	15.92	10.57
HCORN	27.69**	1.76	26.59***	1.35	34.38***	1.07
HCOTTON	19.25*	8.56	15.99**	6.81	10.92**	5.33
HOATS	25.86**	6.13	-14.62***	5.12	-8.93*	5.15
HSORGH	19.59**	3.60	14.56***	2.99	18.26***	4.06
HSOY	11.33**	1.95	7.37***	1.52	3.23***	1.16
HWHEAT	13.17**	2.28	16.68***	1.93	13.34***	1.71
ACRESOP	0.001**	0.0003	0.0005***	0.0002	0.0004***	0.0001
WEALTH	-0.001**	0.0002	0.002***	0.0002	0.0004***	0.0001
DP	-	-	0.13***	0.03	0.34***	0.03
GOV	0.29**	0.03	0.10***	0.02	0.11***	0.02
AGE	-0.05**	0.01	-0.03***	0.01	-0.03***	0.01
TENURE	6.50**	0.52	2.03***	0.48	0.42	0.27
WACF	0.18**	0.07	0.11**	0.05	0.03	0.03
INSURE	-20.96**	5.44	-25.69***	4.78	-13.42***	4.42
SOLVE	4.31**	1.48	2.50*	1.45	0.61	0.71
DP*INSURE	-	-	0.14	0.46	-2.41***	0.43
DP*SOLVE	-	-	-0.23**	0.11	-0.03	0.06
GOV*INSURE	-0.87**	0.34	-0.66***	0.22	-0.59**	0.28
GOV*SOLVE	-0.33**	0.09	0.19***	0.07	-0.03	0.09
TIME	0.11	0.54	-3.13***	0.94	1.14	1.01
TIMESQ	0.04	0.09	0.15***	0.05	-0.01	0.03
Observations	*4,755*		*6,788*		*12,575*	
Adjusted R^2	*0.501*		*0.498*		*0.420*	

Note: *, **, *** indicate parameter significance at α = 10%, 5% and 1%, respectively.

The Chow tests suggest that there are significant differences within these three subsets of the data (years 1991 through 2008) so comparing coefficients across these three subsets indicates which characteristics are unique to each subset. For example, the coefficient for HSOY decreases with each subset, going from about 11 in the first subset, then 7 in the second subset, and finally 3 in the third subset. This implies that within each subset, an increase in the amount of harvested acres of soybeans increases fertilizer expenditures per acre by less and less. Possible causes of this decrease may be changes in soybean production practices or the type of soybeans used due to biotechnology. The effect of HBARLEY is only significant in the first subset. Also, the effect of HOATS is positive and significant (as expected) in the first subset. In the other subsets the coefficient on HOATS are negative and significant, perhaps explaining the much smaller HOATS coefficient of 6.97 seen in Table 6.2: for five years, an increase in harvested acres of oats increased fertilizer expenditures; for the remaining twelve years, the relationship was negative, therefore pulling the coefficient towards zero.

Another interesting relationship emerges when comparing the first subset with the second: with the introduction of decoupled direct payments in 1996, the marginal effect of government payments on fertilizer expenditures per acre evaluated at the mean decreases from 0.20 to 0.08. Between 2002 and 2008, the marginal effect of GOV evaluated at the mean remains almost the same (0.07), but the marginal effect of DP evaluated at the mean increases from 0.12 between 1996 and 2001 to 0.21 from 2002 to 2008. This may imply that after 2002, an increase in decoupled direct payments has a larger impact on fertilizer expenditure per acre operated than prior to the enactment of the

FSRI Act, possibly because of the introduction of updating. When the model is broken into three subsets, the results support the hypotheses: other government payments and decoupled direct payments are significant and positively related to fertilizer expenditures per acre. Future expectations of updating may be an underlying reason that the magnitude of the effects of decoupled direct payments increased after 2002. It is also interesting to note that the marginal effects of decoupled direct payments on fertilizer use is two to three times greater than the marginal effect of other government payments.

Lastly, the effects of the time trend variables TIME and TIMESQ are only significant in the second subset, where the signs imply that between 1996 and 2001, technology and other longitudinal factors decrease fertilizer expenditures at a decreasing rate.

Fertilizers (Structural Breaks in 1996 & 2004)

Table 6.4 looks very similar to Table 6.3. In fact, because the hypothesized break in 1996 holds, the first subset is identical to the first subset in Table 6.3. The first subset has 4,755 observations, the second subset (1996-2003) has 9,747 observations, and the third subset has 9,616 observations. The adjusted R^2 value for each subset is 0.50, 0.41, and 0.45, respectively.

Table 6.4. Fertilizer OLS Regression Results with Structural Breaks in 1996 and 2004

	Subsets					
	1991-1995		1996-2003		2004-2008	
	Coeff.	Std. Error	Coeff.	Std. Error	Coeff.	Std. Error
HCORN	27.69***	1.76	26.69***	1.05	39.49***	1.33
HCOTTON	19.25**	8.56	11.78**	5.10	26.13***	8.74
HSORGH	19.59***	3.60	13.73***	2.50	24.00***	6.57
HSOY	11.33***	1.95	6.36***	1.16	1.06	1.50
HBARLEY	17.52***	6.34	11.52*	7.16	-11.42	17.06
HOATS	25.86***	6.13	-12.55***	4.31	-9.75	6.20
HWHEAT	13.17***	2.28	16.12***	1.62	15.82***	2.02
ACRESOP	0.001***	0.0003	0.0005***	0.001	0.0003**	0.0001
WEALTH	-0.001***	0.0002	0.001***	0.002	0.0005***	0.0001
DP	-	-	0.12***	0.03	0.39***	0.04
GOV	0.29***	0.03	0.09***	0.02	0.09***	0.03
AGE	-0.05***	0.01	-0.03***	0.01	-0.01	0.01
TENURE	6.50***	0.52	2.53***	0.39	0.12	0.30
WACF	0.18***	0.07	0.05	0.04	-0.05	0.04
INSURE	-20.96***	5.44	-26.60***	3.87	-11.96**	5.53
SOLVE	4.31***	1.48	0.97	0.70	9.63***	2.50
DP*INSURE	-	-	0.45	0.40	-2.68***	0.50
DP*SOLVE	-	-	-0.11**	0.05	-0.45**	0.18
GOV*INSURE	-0.87***	0.34	-0.62***	0.18	-0.60	0.46
GOV*SOLVE	-0.33***	0.09	0.12**	0.05	0.01	0.15
TIME	0.11	0.54	-4.00***	0.50	3.33	2.87
TIMESQ	0.04	0.09	0.20***	0.03	-0.07	0.09
Observations	*4,755*		*9,747*		*9,616*	
Adjusted R^2	*0.501*		*0.408*		*0.450*	

Note: *, **, *** indicate parameter significance at α = 10%, 5% and 1%, respectively.

Finding a structural break in 2004 rather than in 2002 when a new policy was enacted indicates that farmers are hesitant to adjust their on-farm production decisions until after they see how the policy will affect their own expected utility function. If a farmer expects government policies to change regularly, it may be optimal to wait and see how the new policy may negatively or positively impact him or her. Because fertilizer is such an integral part of the production of program crops, farmers might be more likely to hold off on changing input decisions regarding fertilizer and other agricultural chemicals. However, these conjectures are unnecessary: an additional Chow test was performed to see if this restricted model with breaks in 1996 and 2004 is significantly different than the expected model with structural breaks in 1996 and 2002. The results indicate that there is no statistically significant difference between this model and the model described in Table 6.3 (F-test=0.858, p=1). Therefore, the hypothesized breaks for fertilizer hold.

The marginal effects of government payments and decoupled direct payments evaluated at the means in each of the subsets are also similar to the model with expected breaks in 1996 and 2002 (results in Table 6.3). Between 1991 and 1995, the marginal effect of government payments on fertilizer expenditures is 0.20, between 1996 and 2003 the marginal effect is 0.07, and between 2004 and 2008 the marginal effect is 0.06. The marginal effect of decoupled direct payments evaluated at the mean on fertilizer expenditures between 1996 and 2003 is 0.14 and increases to 0.21 between 2004 and 2008.

Other Agricultural Chemicals (Structural Breaks in 1996 & 2002)

Table 6.5 shows the results for the model with other agricultural chemical expenditures per acre operated as the dependent variable with structural breaks in 1996 and 2002. The first subset includes years 1991 through 1995, the second subset 1996 through 2001, and the third subset 2002 through 2008.

Table 6.5. Other Agricultural Chemicals Weighted OLS Regression Results with Structural Breaks in 1996 and 2002

	Subsets					
	1991-1995		1996-2001		2002-2008	
	Coeff.	Std. Error	Coeff.	Std. Error	Coeff.	Std. Error
HBARLEY	0.49	5.18	3.10	7.04	5.75	7.08
HCORN	15.89***	0.98	16.77***	0.82	13.55***	0.61
HCOTTON	35.94***	8.00	21.00***	6.13	22.92***	4.42
HOATS	-11.59**	5.41	-13.72***	4.43	-0.42	3.58
HSORGH	3.31	2.88	18.24***	2.39	12.73***	2.70
HSOY	11.01***	1.00	14.77***	0.75	9.24***	0.55
HWHEAT	8.01***	2.44	10.80***	1.97	7.66***	1.31
ACRESOP	0.0006***	0.0002	0.0004***	0.0001	0.0002***	0.00008
WEALTH	0.0004***	0.0001	0.0005***	0.0001	0.0002***	0.00007
DP	-	-	0.26***	0.03	0.18***	0.02
GOV	0.15***	0.02	-0.02	0.02	0.03**	0.02
AGE	-0.03***	0.01	-0.01	0.01	0.01	0.01
TENURE	2.53***	0.41	2.13***	0.38	0.22	0.18
WACAC	0.12	0.09	0.08	0.07	0.25***	0.06
INSURE	-23.17***	4.37	-15.53***	3.81	-7.57***	2.95
SOLVE	3.75***	1.19	4.14***	1.16	0.23	0.47
DP*INSURE	-	-	-1.65***	0.37	-0.91***	0.28
DP*SOLVE	-	-	-0.26***	0.09	-0.001	0.04
GOV*INSURE	-0.41	0.27	0.86***	0.18	0.16	0.19
GOV*SOLVE	-0.0005	0.07	0.06	0.05	-0.02	0.06
TIME	2.56***	0.48	2.35***	0.69	-0.94	0.68
TIMESQ	-0.32***	0.08	-0.16***	0.04	0.01	0.02
Observations	*4,755*		*6,788*		*12,575*	
Adjusted R^2	*0.430*		*0.426*		*0.322*	

Note: *, **, *** indicate parameter significance at α = 10%, 5% and 1%, respectively.

There are 4,755 observations in the first subset (1991-1995), 6,788 observations in the second subset (1996-2001), and 12,575 observations in the third subset (2002-2008). The adjusted R^2 values are 0.43, 0.43, and 0.32, respectively.

Each of the seven program crops in the model have similar coefficients to the agricultural chemical model presented in Table 6.2, with the exception of HSORGH, which is smaller in magnitude in the first subset, but not statistically significant. Also, the WACAC coefficient is only statistically different from zero in the third subset. This is somewhat surprising as it may suggest that the price of other agricultural chemicals does not affect the other agricultural chemical expenditures per operated acres. Contrary to the fertilizer model with structural breaks in 1996 and 2002, the effects of the time trend variables are both significant in the first two subsets, suggesting that between 1991 and 2001, agricultural chemical expenditures have increased at a decreasing rate.

Comparing the three subsets of the agricultural chemical model, the absence of decoupled direct payments is evident before 1996. After their introduction at that time, there is a positive and statistically significant relationship between DP and agricultural chemical expenditures per acre. In the second subset, both interaction terms with DP are negative. The marginal effect of decoupled payments per acre operated on other agricultural chemical expenditures between 1996 and 2001 is 0.14 evaluated at the mean; between 2002 and 2008, the marginal effect evaluated at the mean is 0.13.

The effect of other government payments is negative in the second subset (1996-2001) but not significant. Otherwise, the effects of government payments per operated acre are similar to the results for the whole time period (Model 2). However, the interaction terms show a weaker relationship in all three subset models relative to the results using all the data. GOV*INSURE is only significant between 1996 and 2001 and GOV*SOLVE is not significant in any of the three subsets. The marginal effect of government payments per acre operated on other agricultural chemical expenditures per acre evaluated at the mean is 0.13 between 1991 and 1995, 0.04 between 1996 and 2001, and 0.04 between 2002 and 2008.

Agricultural Chemicals: Structural Breaks in 1996 & 2000

A Chow test conducted to determine if the model with breaks in 1996 and 2000 is significantly different than the hypothesized model with structural breaks in 1996 and 2002 indicates that there is a statistically significant difference between the hypothesized model with structural breaks in 1996 and 2002 and a model with structural breaks in 1996 and 2000 (F-statistics=1.983, p=0), shown in Table 6.6. The break occurring in 2000 instead of 2002 could be due to farmers' anticipation of new policies. This would be the opposite of what was explained in the previous fertilizer model. However, the most likely cause of this structural break is not policy related. In 2000, the patent for Monsanto's chemical herbicide Roundup expired, reducing the price of glyphosphate (generic Roundup) dramatically and increasing the volume used in the United States (Baccara et al., 2003). Farmers use this herbicide due to the "broad-spectrum weed control, low cost and simplicity" (Shaner, 2000) and have decreased the use of other herbicides in place of using glyphosphate. Additionally, round-up ready crops, which are resistant to this herbicide, have also led to increased use of glyphosphate. It is possible that the effect of increasing use of this chemical after 2000 on other agricultural chemical expenditures dominated any structural break due to policy changes in 2002.

The number of observations in the first subset (1991-1995) is 4,755, the number of observations in the second subset (1996-1999) is 5,060, and the number of observations in the third subset (2000-2008) is 14,303. Respective adjusted R^2 values are 0.430, 0.46, and 0.34. The first subset (1991-1995) is identical to the first subset presented in Table 6.5. The second and third subsets have minimal changes from the previous model with structural breaks at 1996 and 2002, however a few key variables have coefficients that are now statistically significant.

The effect of the ratio of owned-to-operated acres is positive and significant in every subset, indicating that, as a farmer owns more of the total land operated, he or she increases expenditures on agricultural chemicals. Also, the coefficients of the time trend variables are significant in all three subsets; thus between 1991 and 2008, agricultural chemical expenditures have increased at a decreasing rate.

The coefficients on decoupled direct payments and other government payments are both positive in all three subsets, but the coefficient on government payments is only significant in the first subset (1991-1995). The effect of the interaction term between DP and insurance expenditures is negative and significant from 1996 through 2008, implying that the marginal effects of decoupled direct payments on agricultural chemical expenditures decreases as insurance expenditures increase. The coefficient on DP*SOLVE is negative but smaller; however, for the third subset (2000-2008), the effect is not statistically different than zero. The marginal effect of decoupled direct payments on agricultural chemical expenditures evaluated at the mean between 1996 and 1999 is 0.22 and 0.09 after 2000. The marginal effect of other government payments on agricultural chemical expenditures evaluated at the mean is 0.13 before decoupled direct payments are introduced, 0.07 between 1996 and 1999, and 0.03 after 2000.

Table 6.6. Other Agricultural Chemicals OLS Regression Results with Structural Breaks in 1996 and 2000

	Subsets					
	1991-1995		1996-1999		2000-2008	
	Coeff.	Std. Error	Coeff.	Std. Error	Coeff.	Std. Error
HCORN	15.89***	0.98	12.83***	1.03	14.95***	0.54
HCOTTON	35.94***	8.00	17.17**	7.90	26.35***	3.97
HSORGH	3.31	2.88	11.44***	2.87	15.04***	2.66
HSOY	11.01***	1.00	14.55***	0.94	10.45***	0.49
HBARLEY	0.49	5.18	-0.45	8.23	1.23	6.34
HOATS	-11.59**	5.41	0.42	5.27	-9.79***	3.29
HWHEAT	8.01***	2.44	8.68***	2.45	10.00***	1.21
ACRESOP	0.0006***	0.0002	0.0002	0.0002	0.0003***	0.00008
WEALTH	0.0004***	0.0001	0.0001***	0.0002	0.0003***	0.00007
DP	-	-	0.37***	0.03	0.14***	0.02
GOV	0.15***	0.02	0.03	0.03	0.01	0.01
AGE	-0.03***	0.01	-0.02**	0.01	0.01	0.01
TENURE	2.53***	0.41	1.13**	0.47	0.54***	0.18
WACAC	0.12	0.09	0.23***	0.09	0.20***	0.05
INSURE	-23.17***	4.37	-14.95***	4.40	-11.70***	2.75
SOLVE	3.75***	1.19	7.19***	1.56	0.39	0.46
DP*INSURE	-	-	-1.67***	0.45	-0.80***	0.25
DP*SOLVE	-	-	-0.57***	0.12	-0.04	0.03
GOV*INSURE	-0.41	0.27	0.41	0.31	0.29**	0.12
GOV*SOLVE	0.00	0.07	0.12	0.10	0.05	0.03
TIME	2.56***	0.48	11.81***	2.04	2.13***	0.33
TIMESQ	-0.32***	0.08	-0.83***	0.14	-0.09***	0.01
Observations	*4,755*		*5,060*		*14,303*	
Adjusted R^2	*0.430*		*0.458*		*0.339*	

Note: *, **, *** indicate parameter significance at α = 10%, 5% and 1%, respectively.

Summary

In this chapter, descriptive statistics are presented to illustrate farm and farmer characteristics that might impact the farmer's decision-making process. Regression results for both fertilizer and other agricultural chemical expenditures per acre operated (FERT and CHEM) are analyzed 1) for the whole sample period (1991-2008), 2) with structural breaks in 1996 and 2002, and 3) with structural breaks in years found through an iterative Chow test.

All model results indicate that increases in decoupled direct payments have positive affects on fertilizer and other agricultural chemical expenditures per acre with the direct effect captured by the coefficient on DP. This may be due to insurance or wealth effects created by an additional income stream (Hennessy, 1998), or possibly through farmer's expectations of updating (Bhaskar & Beghin, 2010), or a reduction in credit constraints (Goodwin & Mishra, 2006). The marginal effects of government payments and decoupled direct payments on both dependent variables (FERT and CHEM) are positive, as seen in Appendix Tables C.1 and C.2.

The marginal effects of decoupled direct payments on fertilizer and other agricultural chemicals evaluated at the mean are two to three times greater than the marginal effects of government payments evaluated at the mean. As noted in the discussion for Model 1, since lump sum payments could not be separated from coupled payments, the marginal effects of other government payments on fertilizer and other agricultural chemical expenditures serves as a lower bound on the effects of fully coupled payments (in the form of price floors or per unit subsidies).

These results are in line with the tested hypothesis: There is a positive and significant effect of decoupled direct payments (DP) and all other forms of government payments (GOV) on both fertilizer and other agricultural chemical expenditures per acre. Since both dependent variables (FERT and CHEM) and the independent variables (GOV and DP) are normalized with respect to total acres operated, these effects are not due to farm size. Furthermore, because FERT and CHEM are adjusted using a sector specific PPI and DP and GOV are adjusted using CPI, these effects are not caused by inflation.

Between 1991 and 2008, the average government payment per acre operated (GOV) is almost twice the average decoupled direct payment per acre operated (DP). However, the average DP estimate within that period is low because it includes 5 years of zero decoupled payments (1991-1995). Between 1991 and 1995, the average government payment per acre was \$11.87. Between 1996 and 2001, average GOV fell slightly to \$10.90 and average DP was \$7.49. Interestingly, after updating was allowed in the 2002 Farm Bill, average decoupled direct payments stayed almost the same (\$7.40) while other government payments (lump sum and coupled payments) declined to \$6.61. Because DP have a greater marginal effect on agricultural chemicals than GOV, this movement towards decoupled payments may result in a greater distortion in production through changes to the intensive margin.

As stated in the hypothesis, the magnitude of the effect of decoupled direct payments depends on the payout rates for decoupled direct payments and coupled payments, the discount rate δ, and the subjective probability of updating γ. The results indicate that the payout rate for decoupled payments is greater than the payout rate for other government payments after 2002 and the marginal effect of DP on agricultural expenditures does increase after 2002. The regression analysis does not provide a measure of the discount rate or the subjective probability of updating. However, these are factors of the magnitude of the effect of decoupled payments on agricultural chemicals. If the discount rate δ is low, farmers will allocate more resources to realizing future benefits associated with updating. In other words, a patient farmer will forego benefits today to gain future benefits. If the subjective probability of updating is collectively large (close to 1) for all farms, the impact of policy updates will play an important role in the magnitude of the effect of decoupled direct payments. The final chapter describes the policy implications of these results.

CHAPTER SEVEN

IMPLICATIONS AND CONCLUSIONS

Decoupled direct payments were introduced to U.S. agricultural policy in 1996 with production flexibility contract payments paid to farm operators based on historic acreage and yields, not production, prices, or inputs. This change was motivated by the 1994 Uruguay Round Agreement on Agriculture requiring World Trade Organization member countries to reduce trade distorting agricultural policies. Decoupled payments were continued in the two subsequent farm bills. The Farm Security and Rural Investment Act of 2002 gave farmers the option of updating base acreage and yields, essentially changes the calculations upon which decoupled payments are based. The Food, Conservation, and Energy Act of 2008 gave farmers the option of foregoing a portion of their decoupled direct payments to obtain Average Crop Revenue Election (ACRE) program payments based on national market price and state Olympic moving average yields.

The literature reviewed has identified several mechanisms by which decoupled payments have the potential to distort production in the current period. First, risk averse producers may increase production due to insurance and wealth effects associated with the decoupled payments. Second, in imperfect credit markets decoupled payments may ease constraints by increasing total wealth. Third, current production decisions may be influenced by expectations of future decoupled payments, especially if updating is anticipated. Fourth, input markets are affected through possible changes in the allocation of labor and land, due to the capitalization of decoupled payments in land values. Lastly, exit deterrence may result in fewer farms leaving the market due to subsidizing fixed costs, declining average costs, or cross-subsidization. If decoupled direct payments are coupled to production decisions, farmers may increase their use of production inputs including environmentally harmful agricultural chemicals.

This thesis tested the hypothesis that there exists a positive and significant relationship between both decoupled direct payments and coupled government payments and the use of fertilizers and other agricultural chemicals per acre. Since quantity data was not available and prices are controlled for, expenditures per acre serve as a proxy for the quantity of agricultural chemicals used. The relationship between both coupled government payments and decoupled direct payments and agricultural chemical use was expected to be positive and the theoretical model illustrated that the magnitude of the effect of decoupled direct payments relative to the effect of coupled government payments depended on the sizes of coupled price supports and decoupled farm subsidies, the subjective probability of updating, and the discount rate. Additionally, structural breaks were expected around the time of policy changes in 1996, 2002, and 2008 due to expectations of updating.

Using USDA Farm Cost and Return Survey and Agricultural Resources and Management Survey data from 1991 to 2008, weighted ordinary least squares regression analysis was conducted to test the hypothesis. The model allowed decoupled and other government payments to affect fertilizer and other agricultural chemical expenditures per acre in three ways: directly, captured by the coefficients of decoupled payments and other government payments, and indirectly through two interaction terms with a farmer's level of risk aversion and financial risk. The direct effects are positive for both types of government payments, as expected. The indirect effects captured by the interaction terms were negative, suggesting that the effects of government payments decrease at higher levels of risk aversion and financial risk.

Thus, government payments can ease credit constraints under imperfect credit markets by increasing a farmer's total wealth (Goodwin & Mishra, 2006). Moreover, decoupled direct payments and other government payments can affect a farmers risk preferences by increasing total assets. Similarly, decoupled direct payments and other government payments can reduce levels of risk aversion by guaranteeing a level of revenue that is not tied to production (Hennessy, 1998).

The marginal effects evaluated at the mean of both types of government payments were positive. Furthermore, the magnitude of the marginal effects of decoupled direct payments on fertilizer and other agricultural chemicals expenditures per acre evaluated at the means was two to three times greater than the marginal effects of other government payments.

Because data is not available after 2008, the regression analysis was not used to test for changes in production decisions due to policy changes in the 2008 Farm Bill. However, the theoretical model illustrates that the ACRE program may be implicitly coupled to production because base yield is determined by an Olympic moving average that changes every year. Therefore, farmers have the opportunity to change base yield each year and will do so in order to maximize their expected utility of wealth.

Implications

The results may have significant implications for future agricultural policies. The marginal effects of decoupled direct payments on fertilizer and other agricultural chemicals expenditures per acre evaluated at the mean was two to three times greater than the marginal effect of other government payments evaluated at the mean, suggesting that decoupled payments affect the intensive margin more than other government payments. Thus, decoupled payments can be more production distorting and possibly more environmental harmful than other government payments. Since in the model other government payments included non-distortive lump sum payments and fully coupled price supports, the effect of government payments on fertilizer and other agricultural chemical expenditures per acre serves as a lower bound on the effect of coupled price supports. However, it is likely that coupled payments make up the majority of other government payments.

Hence, the results of the empirical model suggest that the move towards decoupled payments may lead to greater production distortions through their affect on the intensive margin. The results also support previous research that a farmer’s expectation of future updating acts as a coupling mechanism linking decoupled payments to production (Bhaskar & Beghin, 2010; Coble, Miller, & Hudson, 2008).

Although changes to production decisions from the newest decoupled direct payment program, ACRE, could not be tested empirically, an important implication is that the ACRE program introduced in 2008 set historic yield to an Olympic moving average, meaning that each year the historic period changes. This policy may create a link between current acreage and input decisions and future program crop payments and therefore be in violation of standing World Trade Organization (WTO) agreements.

The theoretical and empirical results have major implications for the future of U.S. agricultural policies as well as international policies within the WTO. The 1994 Agreement on Agriculture required member countries to reduce production distorting policies, leading the US to introduce decoupled payments. However, if these types of payments have a larger affect on agricultural chemical use than coupled payments, the introduction of decoupled payments may have increased production distortions via their impact on the intensive margin rather than decreasing production distortions as intended. Thus, even WTO sanctioned 'green box' policies may distort production. Furthermore, the movement towards decoupled payments in the US and away from coupled payments may increase agricultural chemical use, with negative impacts on the rural environment.

If the US wants to support farmers' income without distorting production, policies must be implemented on a one-time basis and not updated every four to seven years. The original intention of the 1996 FAIR Act was to introduce a temporary decoupled payment program (production flexibility contracts) that would be eliminated after seven years. In 2002, production flexibility contracts were eliminated only to be replaced by two other decoupled payments (fixed direct payments and countercyclical payments) Hence, Milton Friedman may have been correct to say, "Nothing is so permanent as a temporary government program" and farmers recognize that once implemented, policies tend to stick around.

Limitations and Further Research

To more fully understand the link between decoupled payments, updating and agricultural chemical use more research is needed to overcome the limitations of this research. First, the lack of panel data means that year-to-year changes in a specific farmer's production decisions could not be tracked. The use of panel data would grant a better understanding of how both the extensive and intensive production margins are impacted by policy changes.

Furthermore, Phase III data only includes aggregate total expenditures of fertilizer and other agricultural chemicals, not actual quantities per acre. Quantities of fertilizer and agricultural chemicals per acre should be used in the analysis rather farm-level total expenditures to gain a better understanding of how different types of government payments affect the intensive margin. Phase II data contains input quantities data on a crop specific field-level basis, but Phase II data does not contain information about decoupled payments because these payments are received at the farm-level, not the field-level. A limited analysis could be conducted using the small number of farms that are questioned during both Phase II and Phase III. Quantity data could also be used to determine how decoupled direct payments affect environmental quality by examining the use of particularly environmentally hazardous agricultural chemicals.

Additionally, because the data available did not separate other government payments into lump sum payments and coupled price supports, it was not possible to examine the exact magnitude of the effect of decoupled direct payments relative to coupled payments. Future research should aim to further separate other government payments into lump sum transfers and coupled payments.

This thesis focused on the effect of government payments on the use of agricultural chemicals. However, similar models could analyze other non-farm inputs to determine if the affect of government payments on the intensive margins of these inputs is similar. Lastly, the theoretical model illustrating that ACRE program payments implicitly create a link between current acreage and input decisions and future program crop payments should be tested empirically by analyzing data after the 2008 Farm Bill.

APPENDICES

Appendix A

Comparison of Partially and Fully Decoupled Payments

Table A.1. Comparison of PFC, DP, CCP & ACRE Programs in U.S. Farm Bills

	Production Flexibility Contracts	**Fixed Direct Payments**	**Counter-Cyclical Payments**	**Acreage Crop Revenue Election**
Years	1996 – 2002	2002 – 2012	2002 – 2012	2008 - 2012
Type of Policy	Fully decoupled		Partially decoupled, linked to price not production	
Total Expenditure	$5 – 6 billion annually		~ $4 billion annually	unknown
Program Crops	Wheat, corn, barley, grain sorghum, oats, upland cotton, and rice.	Wheat, corn, barley, grain sorghum, oats, upland cotton, rice, soybeans, other oilseeds, and peanuts.		Wheat, corn, barley, grain sorghum, oats, upland cotton, rice, soybeans, other oilseeds, peanuts, dry peas, lentils, small chickpeas, and large chickpeas
Eligibility	One time enrollment for 7 year contract	Annual agreement, allows for advance payments up to 50% before harvest	Annual agreement, must decide how to define base acres and payment yield	Alternative to receiving CCPs; must remain enrolled until 2012; program reduces all fixed direct payments to the farm by 20%
Calculation of Payment Yield	Set for each commodity in FAIR Act	Set for each commodity in FSRI Act	1. Use current program yields, OR update to: 2. Program Yields + {70% of (Farm's average yield from 1998 to 2001) – (Current program Yields)} 3. 93.5 % of 1998-2001 average yields.	Benchmark State yield is a commodity and state specific measure of the moving Olympic average yield per planted acre.
Calculation of Payment Acres	85% of base acres in selected commodity	CY 2002 – 2008: 85% of base acres in selected commodity CY 2009 – 2011: 83.3% of base acres planted or considered planted in selected commodity	1. Payment acreage that would have been used for 2002 PFC payments + average oilseed plantings in 1998-2001 OR 2. 4-year average of total acres planted + those unable to be planted due to weather conditions in 1998-2001	CY 2009-2011: 83.3% of base acres planted or considered planted in selected commodity CY 2012: 85% of base acres in selected commodity

Sources: (ERS, 2002; ERS, 2008; Young & Shields, 1996)

Appendix B

Descriptive Statistics

Table B.1. Average Harvested Acreage of Program Crops in Extended Heartland Region, 1991-2008

	Illinois	Indiana	Iowa	Kentucky	Minnesota	Missouri	Nebraska	Ohio	South Dakota
Corn	278.5	243.6	228.3	103.6	184.5	134.5	299.8	160.3	234.8
Cotton	0.0	0.0	0.0	0.0	0.0	14.3	0.0	0.0	0.0
Rice	0.0	0.0	0.0	0.0	0.0	8.5	0.0	0.0	0.0
Sorghum	1.8	0.5	0.0	1.9	0.0	13.8	24.8	0.1	5.2
Soybean	245.3	224.2	198.5	111.7	201.2	239.2	140.5	212.0	245.5
Barley	0.1	0.0	0.0	0.1	10.1	0.3	0.1	0.2	5.5
Oats	1.0	0.2	2.8	0.1	3.4	0.8	1.7	0.8	7.8
Wheat	18.0	16.8	0.6	15.3	72.4	38.7	66.7	43.5	179.8
Oilseed	0.0	0.1	0.0	0.0	4.2	0.0	1.9	0.0	24.9
Pulse Crop	0.0	0.0	0.0	0.0	4.0	0.1	5.4	0.0	1.8
Peanuts	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

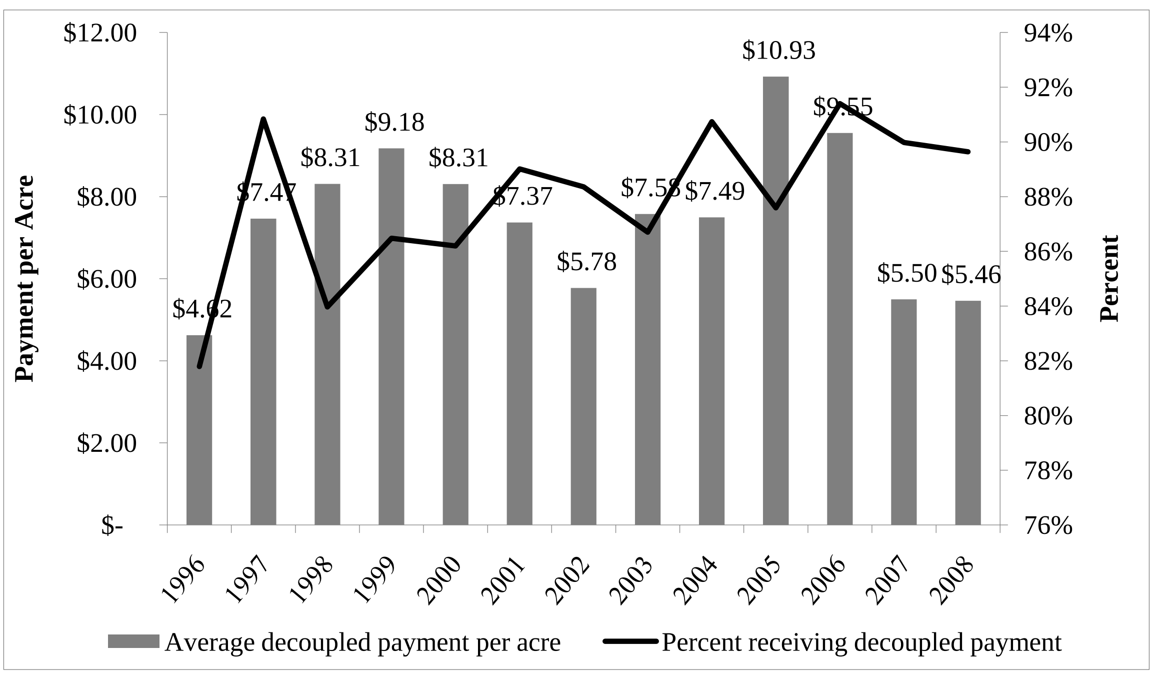

Figure B.1. Average Decoupled Payments per Acre in Extended Heartland Region, 1996-2008

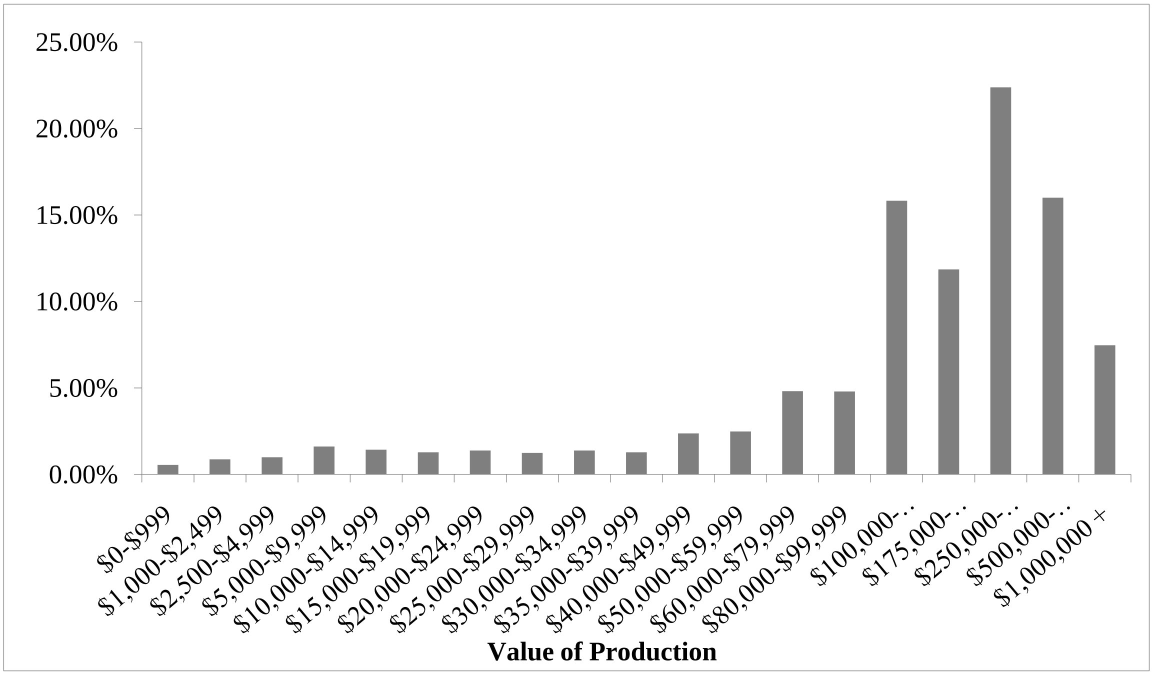

Figure B.2. Value of Production in Extended Heartland Region, 1991-2008

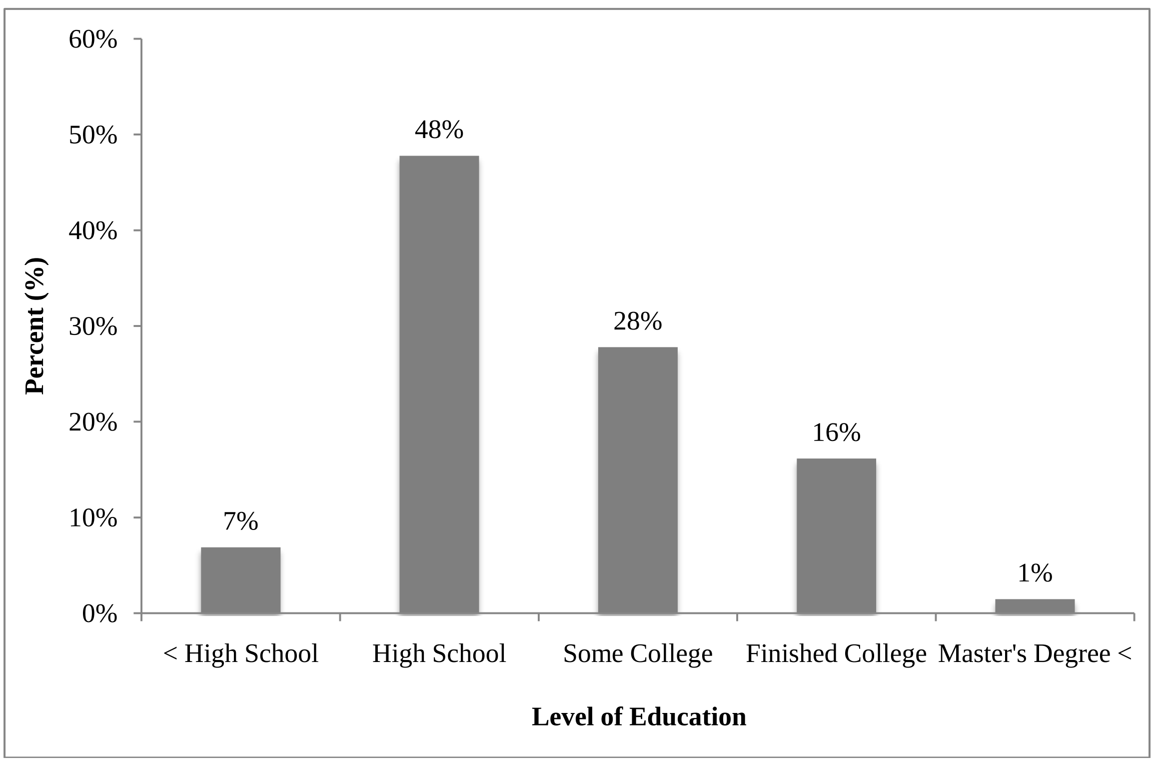

Figure B.3. Primary Operator’s Level of Education in Extended Heartland Region, 1991-2008

Appendix C

Marginal Effects of Government Payments, Insurance, and Solvency

Table C.1. Marginal Effects of Decoupled Direct Payments, Other Government Payments, Insurance, and Solvency on Fertilizer Expenditures Evaluated at the Mean

	Marginal Effects Evaluated at the Mean				Mean			
	GOV	DP	INSURE	SOLVE	GOV	DP	INSURE	SOLVE
Whole Model								
1991-2008	0.08	0.14	-32.25	0.86	9.81	4.88	0.06	0.10
Expected Breaks								
1991-1995	0.20	-	-31.31	0.37	11.87	-	0.05	0.12
1996-2001	0.08	0.12	-31.82	2.85	10.90	7.49	0.06	0.10
2002-2008	0.07	0.21	-35.13	0.22	6.61	7.40	0.06	0.08
Actual Breaks								
1991-1995	0.20	-	-31.31	0.37	11.87		0.05	0.12
1996-2003	0.07	0.14	-29.33	1.40	9.66	7.27	0.06	0.11
2004-2008	0.06	0.21	-36.97	6.24	7.21	7.72	0.06	0.06

Notes: Marginal effects of decoupled direct payments per acre (DP) and all other government payments per acre (GOV) on fertilizer expenditures per acre operated are evaluated at the mean of the ratio of insurance costs to total expenditures (INSURE) and ratio of total farm financial debt to total farm financial assets (SOLVE). Marginal effects of INSURE and SOLVE are evaluated at the mean of DP and GOV. GOV, DP, INSURE, and SOLVE are adjusted using CPI; fertilizer expenditures are adjusted using PPI.

Table C.2. Marginal Effects of Decoupled Direct Payments, Other Government Payments, Insurance, and Solvency on Other Agricultural Chemical Expenditures Evaluated at the Mean

	Marginal Effects Evaluated at the Mean				Mean			
	GOV	DP	INSURE	SOLVE	GOV	DP	INSURE	SOLVE
Whole Model								
1991-2008	0.06	0.11	-17.98	2.34	9.81	4.88	0.06	0.10
Expected Breaks								
1991-1995	0.13	-	-23.17	3.75	11.87		0.05	0.12
1996-2001	0.04	0.14	-15.53	4.14	10.90	7.49	0.06	0.10
2002-2008	0.04	0.13	-7.57	0.23	6.61	7.40	0.06	0.08
Actual Breaks								
1991-1995	0.13	-	-23.17	3.75	11.87		0.05	0.12
1996-1999	0.07	0.22	-14.95	7.19	6.62	7.34	0.06	0.10
2000-2008	0.03	0.09	-11.70	0.39	9.82	7.50	0.06	0.08

Notes: Marginal effects of decoupled direct payments per acre (DP) and all other government payments per acre (GOV) on other agricultural chemical expenditures per acre are evaluated at the mean of the ratio of insurance costs to total expenditures (INSURE) and ratio of total farm financial debt to total farm financial assets (SOLVE). Marginal effects of INSURE and SOLVE are evaluated at the mean of DP and GOV. GOV, DP, INSURE, and SOLVE are adjusted using CPI; agricultural chemical expenditures are adjusted using PPI.

Appendix D

Estimation of Structural Breaks

Table D.1. Iterative Chow Test Statistics Estimating Structural Breaks Around Policy Changes in 1996, 2002, and 2008: Fertilizer Model

	2 Breaks					3 Breaks (include 2006)				
	2000	*2001*	*2002*	*2003*	*2004*	*2000*	*2001*	*2002*	*2003*	*2004*
1994	16.16	15.30	15.72	16.81	17.63	14.00	13.26	13.21	13.43	13.68
1995	15.07	14.34	14.91	16.31	17.30	13.28	12.61	12.67	13.11	13.46
1996	16.44	16.94	18.05	19.26	20.40	14.19	14.33	14.72	15.03	15.52
1997	14.71	15.11	16.09	17.35	18.34	13.13	13.22	13.55	13.94	14.33
1998	14.53	14.68	15.86	17.10	17.96	12.97	12.92	13.39	13.76	14.08

Note: Largest F-statistic (20.40) found in test for structural breaks in 1996 and 2004. However, an additional F-test comparing model with breaks in 1996 and 2004 to hypothesized model with breaks in 1996 and 2002 found no significant difference (F-stat=0.858, p=1).

Table D.2. Iterative Chow Test Statistics Estimating Structural Breaks Around Policy Changes in 1996, 2002, and 2008: Other Agricultural Chemicals Model

	2 Breaks					3 Breaks (Include 2006)				
	2000	*2001*	*2002*	*2003*	*2004*	*2000*	*2001*	*2002*	*2003*	*2004*
1994	13.60	11.69	12.50	10.84	11.34	10.92	9.77	9.56	8.66	8.51
1995	13.85	11.90	12.59	11.05	11.41	11.08	9.88	9.61	8.78	8.55
1996	15.03	12.72	13.46	12.21	12.63	11.85	10.43	10.19	9.55	9.35
1997	14.17	12.76	13.92	13.58	14.08	11.42	10.56	10.63	10.57	10.47
1998	11.92	10.84	11.99	11.89	12.21	9.85	9.26	9.32	9.43	9.20

Note: Largest F-statistic (15.03) found in test for structural breaks in 1996 and 2000. An additional Chow test comparing model with breaks in 1996 and 2000 to hypothesized model with breaks in 1996 and 2002 found a statistically significant difference (F-stat=1.983, p=0).

REFERENCES

Abler, D., and D. Blandford. 2005. *A Review of Studies of the Acreage and Production Response of U.S. Production Flexibility Contract Payments Under the FAIR Act and Related Payments*. Paris: OECD [Report AGR/CA/APM (2004) 21/FINAL].

Adams, G., P. Westhoff, B. Willott, and R. E. Young. 2001. "Do "Decoupled" Payments Affect U.S. Crop Area? Preliminary Evidence from 1997-2000." *American Journal of Agricultural Economics* 83(5): 1190-1195.

Ahearn, M. C., H. El-Osta, and J. Dewbre. 2006. "The Impact of Coupled and Decoupled Government Subsidies on Off-Farm Labor Participation of U.S. Farm Operators." *American Journal of Agricultural Economics* 88(2): 393.

Alston, J. M. and B. H. Hurd. 1990. "Some Neglected Social Costs of Government Spending in Farm Programs" *American Journal of Agricultural Economics*, 72(1): 149-156.

Baccara, M., Backus, D., Bar-Isaac, H., White, L., & Cabral, L. (2003). *Monsanto's Roundup: Firms and Markets Mini-case*. New York: NYU Stern.

Baffes, J., and H. de Gorter. 2005. "Disciplining Agricultural Support through Decoupling." Working paper 3533, World Bank Policy Research Center.

Bai, J., and P. Perron. 2003. "Computation and Analysis of Multiple Structural Change Models." *Journal of Applied Econometrics* 18(1): 1-22.

Bhaskar, A., and J. C. Beghin. 2010. "Decoupled Farm Payments and the Role of Base Acreage and Yield Updating Under Uncertainty." *American Journal of Agricultural Economics* 92(3):849-858.

Blandford, D., H. de Gorter, and D. Harvey. 1989. "Farm Income Support with Minimal Trade Distortions." *Food Policy* 14(3): 268-273.

Borges, R. B. and W. N. Thurman. 1994. "Marketing Quotas and Random Yields: Marginal Effects of Inframarginal Subsidies on Peanut Supply" *American Journal of Agricultural Economics*, 76(4): 809-817.

Burfisher, M. E., and Hopkins, J. 2004. "Introduction." *Decoupled Payments in a Changing Policy Setting*. Washington, DC: U.S. Department of Agriculture, ERS Agr. Econ. Rep. 838, November.

Chand, R., and L. M. Phillip. 2001. "Subsidies and Support in Agriculture: Is WTO Providing Level Playing Field?" *Economic and Political Weekly* 3014-3016.

Chau, N. H., and H. de Gorter. 2005. "Disentangling the Consequences of Direct Payment Schemes in Agriculture on Fixed Costs, Exit Decisions, and Output." *American Journal of Agricultural Economics* 87(5): 1174.

Chow, G. C., 1960. "Tests of Equality between Sets of Coefficients in Two Linear Regressions." *Econometrica: Journal of the Econometric Society* 28(3): 591-605.

Claassen, R. and M. Morehart., 2006. "Greening Income Support and Supporting Green." Washington, DC: U.S. Department of Agriculture, ERS Econ. Brief No. (EB1), March.

Coble, K. H., J. C. Miller, and M. Hudson. 2008. "Decoupled Farm Payments and Expectations for Base Updating." *Review of Agricultural Economics* 30(1): 27-42.

Congress, U. S. 1985. *The Food Security Act of 1985* Public Law, 99: 198.

Cowan, R., and P. Gunby. 1996. "Sprayed to Death: Path Dependence, Lock-in and Pest Control Strategies." *The Economic Journal* 106(436): 521-542.

de Gorter, H., D. R. Just, and J. D. Kropp. 2008. "Cross-Subsidization due to Inframarginal Support in Agriculture: A General Theory and Empirical Evidence." *American Journal of Agricultural Economics* 90(1): 42.

Dixon, O., P. Dixon, and J. Miranowski. 1973. "Insecticide Requirements in an Efficient Agricultural Sector." *The Review of Economics and Statistics* 55(4): 423-432.

Dubman, R. W. 2000. "Variance Estimation with USDA’s Farm Costs and Returns Surveys and Agricultural Resource Management Study Surveys." Washington, DC: U.S. Department of Agriculture, ERS Staff Paper AGES 00–01.

El-Osta, H. S., A. K. Mishra, and M. C. Ahearn. 2004. "Labor Supply by Farm Operators Under ‘Decoupled’ Farm Program Payments." *Review of Economics of the Household* 2(4): 367-385.

ERS. 2002. "2002 Farm Bill: Provisions and Economic Implications." Washington, DC: U.S. Department of Agriculture.

------. 2003. "2003 ARMS Costs and Returns Report Version 1.” Washington, DC: U.S. Department of Agriculture.

------. 2008. "2008 Farm Bill Side-by-Side." Washington, DC: U.S. Department of Agriculture.

-----. 2009. “Commodity Costs and Returns: Methods.” Retrieved April 17, 2010 from http://www.ers.usda.gov/Data/CostsAndReturns/methods.htm

Goodwin, B. K., and A. K. Mishra. 2006. "Are 'Decoupled' Farm Program Payments Really Decoupled? An Empirical Evaluation." *American Journal of Agricultural Economics* 88(1): 73-89.

Heimlich, R. 2000. *Farm Resource Regions*. Washington, DC: U.S. Department of Agriculture, ERS Agr. Inf. Bulletin 760.

Hennessy, David A. 1998. "The Production Effects of Agricultural Income Support Policies Under Uncertainty." *American Journal of Agricultural Economics* 80(1): 46-57.

Horowitz, John K., and E. Lichtenberg. 1993. "Insurance, Moral Hazard, and Chemical Use in Agriculture." *American Journal of Agricultural Economics* 75(4): 926-935.

Johnson, S. R., R. Wolcott, and S. V. Aradhyula. 1990. "Coordinating Agricultural and Environmental Policies: Opportunities and Tradeoffs." *The American Economic Review* 203-207.

Kirwan, B. E. 2009. "The Incidence of U.S. Agricultural Subsidies on Farmland Rental Rates." *Journal of Political Economy* 117(1): 138-164.

Leathers, H. D. and J. C. Quiggin. 1991. "Interactions between Agricultural and Resource Policy: The Importance of Attitudes Toward Risk." *American Journal of Agricultural Economics* 73(3): 757-764.

Lence, S.H., and A.K. Mishra. 2003. “The Impacts of Different Farm Programs on Cash Rents.” *American Journal of Agricultural Economics* 85(3):753-61.

Lichtenberg, E., and D. Zilberman. 1986. "The Welfare Economics of Price Supports in U.S. Agriculture." *The American Economic Review* 76(5): 1135-1141.

Monge-Arino, F. A. 2007. "Decoupled Payments and Agricultural Output: A Dynamic Optimization Model for a Credit-Constrained Farming Household." PhD Dissertation. Ohio State University.

OECD. 2008a. *OECD's Producer Support Estimate and Related Indicators of Agricultural Support: Concepts, Calculations, Interpretation and Use (the PSE Manual)*. Trade and Agricultural Directorate.

------. 2008b. *Producer and Consumer Support Estimates, OECD 1986 – 2008.* Organization for Economic Co-operation and Development.

Orazem, Peter F. and J. Miranowski. 1994. "A Dynamic Model of Acreage Allocation with General and Crop-Specific Soil Capital." *American Journal of Agricultural Economics* 76(3): 385-395.

Plantinga, Andrew J. 1996. "The Effect of Agricultural Policies on Land use and Environmental Quality." *American Journal of Agricultural Economics* 78(4): 1082-1091.

Rajsic, P., A. Weersink, and M. Gandorfer. 2009. "Risk and Nitrogen Application Levels." *Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie* 57(2): 223-239.

Ramaswami, Bharat. 1992. "Production Risk and Optimal Input Decisions." *American Journal of Agricultural Economics* 74(4): 860-869.

Rausser, G. C. 1992. "Predatory Versus Productive Government: The Case of U.S. Agricultural Policies." *The Journal of Economic Perspectives* 6(3): 133-157.

Roosen, Jutta and David A. Hennessy. 2003. "Tests for the Role of Risk Aversion on Input Use." *American Journal of Agricultural Economics* 85(1): 30-43.

Rosine, J., and P. Helmberger. 1974. "A Neoclassical Analysis of the U.S. Farm Sector, 1948–1970." *American Journal of Agricultural Economics* 56 (4): 717–29.

Rucker, R. R., W. N. Thurman, and D. A. Sumner. 1995. "Restricting the Market for Quota: An Analysis of Tobacco Production Rights with Corroboration from Congressional Testimony." *The Journal of Political Economy* 103(1): 142-175.

Sandmo, Agnar. 1971. "On the Theory of the Competitive Firm Under Price Uncertainty" *The American Economic Review* 61(1): 65-73.

Serra, T., D. Zilberman, B. K. Goodwin, and K. Hyvonen. 2005. "Replacement of Agricultural Price Supports by Area Payments in the European Union and the Effects on Pesticide Use." *American Journal of Agricultural Economics* 87(4): 870.

Shaner, D. L. 2000. "The Impact of Glyphosate-Tolerant Crops on the use of Other Herbicides and on Resistance Management." *Pest Management Science* 56(4): 320-326.

Sumner, D. A. 2007. "Farm Subsidy Tradition and Modern Agricultural Realities." American Enterprise Institute Project on Agricultural Policy for the 2007 Farm Bill and Beyond.

Sumner, D. A., and C. A. Wolf. 1996. "Quotas without Supply Control: Effects of Dairy Quota Policy in California." *American Journal of Agricultural Economics* 78(2): 354-366.

Ulibarri, H. F. 1979. "Records of the Office of the Secretary of Agriculture, PI #191." National Archives and Records Administration.

WTO. 1994. "Agriculture: Explanation, domestic support." *World Trade Organization*. http://www.wto.org/english/tratop_e/agric_e/ag_intro03_domestic_e.htm#box (accessed January 2009).

WTO. 2002. "Agriculture: Background Fact Sheet, the Boxes." *World Trade Organization*. http://www.wto.org/english/tratop_e/agric_e/agboxes_e.htm (accessed December 2009.

Wu, J., 1999. "Crop Insurance, Acreage Decisions, and Nonpoint-Source Pollution." *American Journal of Agricultural Economics* 81(2): 305-320.

Young, C. E., and D. A. Shields. 1996. "1996 FAIR Act Frames Farm Policy for 7 Years." Washington, DC: U.S. Department of Agriculture. Agricultural Outlook.

Young, C. E., and P. C. Westcott. 2000. "How Decoupled is U.S. Agricultural Support for Major Crops?" *American Journal of Agricultural Economics* 82(3): 762-767.